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WEEKLY September 26 - October 2, 2015

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our anatomy ever

STUFF OF DREAMS
If it doesn't exist, you
can make it anyway

SHOCK AND ORE
Mining threat to temple
that survived Taliban

BETTER BY DESIGN The case for genetically engineered humans

WHEN RIGHT IS WRONG

How modern living
messes up our moral
compass

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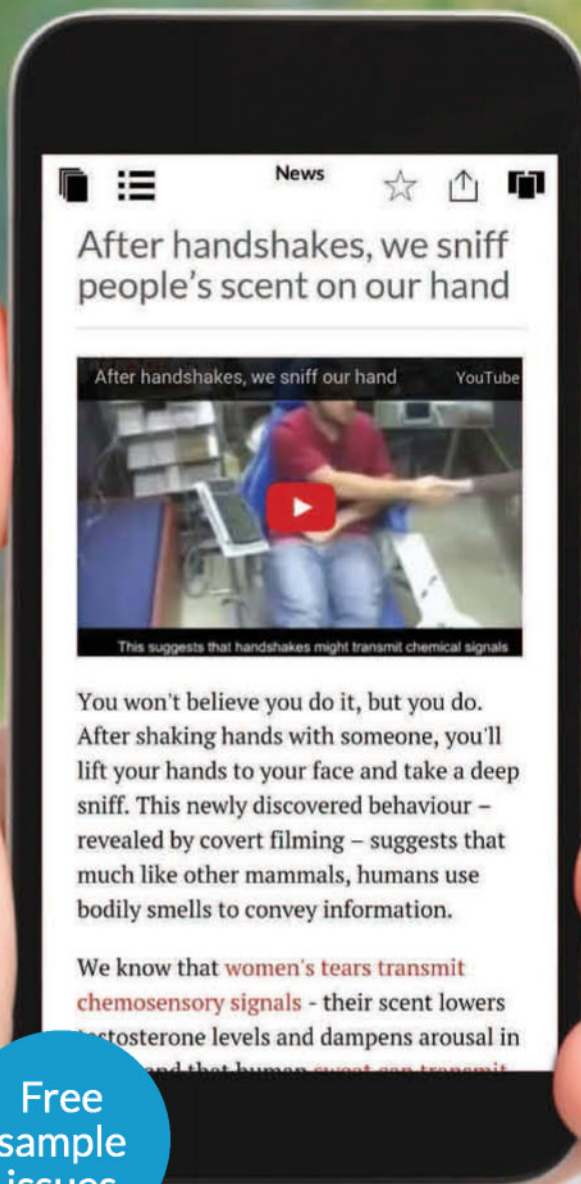


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DITCH THE TURING TEST The real trials of artificial intelligence



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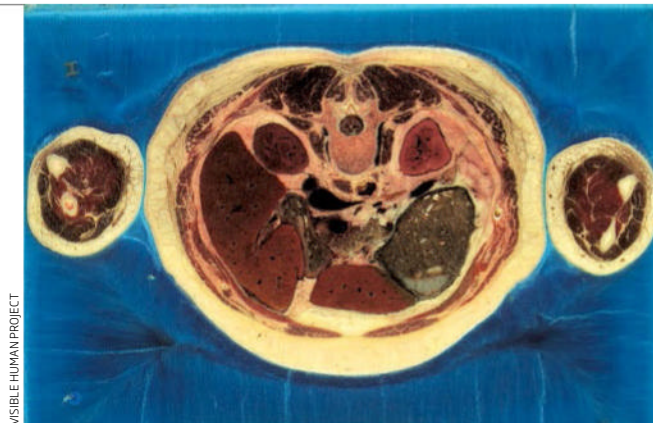
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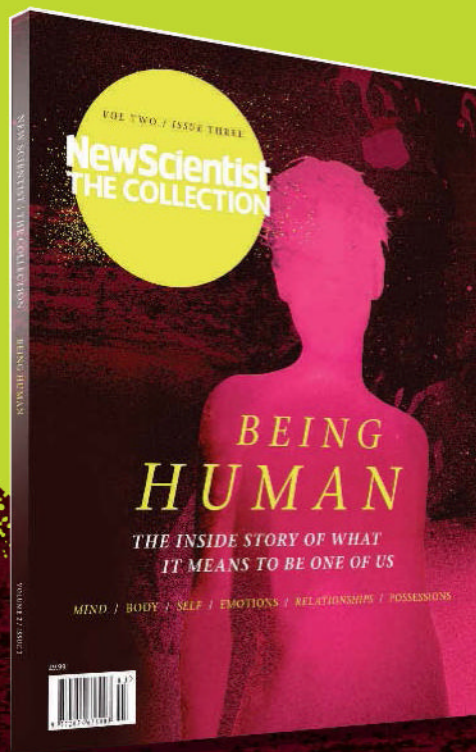
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PAWEŁ JONCA

Fixing our moral compass

Can we rely on science to make us better people?

"WE MUST learn not to take traditional morals too seriously." So said the biologist J.B.S. Haldane in a 1923 talk on science and the future. Haldane predicted that scientific progress would be disruptive to every belief, value and institution. The future would be bright only "if mankind can adjust its morality to its powers".

Haldane had a point: our powers have led to challenges without precedent. Climate change is a threat unlike any we have ever seen (11 July, p 28). Our machines might become smarter than us (see page 20). Genetic engineering could change humanity forever (see page 28).

In the face of such challenges, our evolved moral sense often proves inadequate (see page 36). Part of the problem is sheer scale. The anthropologist Robin Dunbar says we can maintain no more than about 150 meaningful relationships at once. But today, all 7 billion of us are connected – if not in meaningful relationships, not in meaningless ones, either. "Society" is now too expansive a concept for our brains to parse.

One result is conflicting demands that are hard to resolve. The plight of our fellow humans in vulnerable parts of the world compels us to deploy every possible climate change mitigant.

But that could hurt our own way of life. And then there's the urge to just forget all that stress and get on a plane to somewhere sunny.

Given this cognitive overload, our primal emotional responses tend to win out. We do what feels right. But such responses don't necessarily produce the best outcomes. So how can we make sure we do what really is right?

It will take evolution a long time to catch up, if it ever does. So it is down to us to ensure that we are

"We are not simply prisoners of our emotions: we can reason our way to workable compromises"

doing the right thing. It's a tall order, but never fear: moral philosophers are on the case.

Some, such as those based at the Centre for Effective Altruism in Oxford, UK, aim to maximise the good we can do by quantifying the outcomes of our actions. Many of their suggestions have raised eyebrows: that it may be better to become a generous banker than work for a charity, for example. And their approach has been criticised for relying on the status quo and as being inhumane, because it may prioritise the well-being of distant strangers over those closer to home.

Others suggest modifying our moral brains directly, through a hit of drugs or a zap of electricity (see page 19). The difficulties with this idea are obvious: who decides what constitutes improvement? The history of moral re-education is long and ugly, most recently manifest in the inverted values of the so-called Islamic State. And setting such dystopian scenarios aside, wouldn't this rob people of their moral autonomy? Letting someone else direct our sense of right and wrong would strike many as, well, immoral.

Its proponents claim these issues are not much different to those raised by conventional moral instruction (see page 26). But if so, and given the practical difficulties of large-scale morality hacking, we should perhaps stick to education. We are not simply prisoners of our emotions: we can reason our way to workable compromises. Science alone will not get us there: if there is a 21st century moral duty, it is to learn how to think through the ethics, law, sociology and even spiritual aspects of a problem.

So no, we shouldn't take traditional morality too seriously where it fails to address modern problems. But the basic humanity that gives rise to its flaws can also lead us to its successor. ■



One of many

Fires ravage California

CALIFORNIA is burning. One of the worst wildfire seasons in the state's history has killed six people and destroyed over a thousand homes, California's Department of Forestry and Fire Protection said on Monday.

Hundreds of thousands of hectares across the western US – from Alaska to California – are alight with multiple wildfires. But only California, the most populous state in the country, has seen deaths and widespread property damage.

The fires are stoked by drought, in California's case the worst its history. Earlier this year, officials went to measure the snowpack in the Sierra Nevada mountain range, which provides much of the state's water. Instead of the traditional 1.5 metres of snow, they found just dry earth. This

year's snowpack is at a 500-year low, thanks to unusually warm winter weather and poor snows – conditions that are expected to become more common as climate change hits.

Climate change is widely acknowledged as being behind the severity of the drought. Warmer temperatures mean precipitation is more likely to fall as rain rather than snow. Rain runs off the mountains fast rather than piling up into a natural water reserve as snow does.

Uneven heating of the planet also moves precipitation zones – in California's case, shifting the tracks of winter storms that roll in off the Pacific Ocean. This year's El Niño is expected to bring rains to California, but it is unlikely to be enough to end the drought.

United on poverty

IT MIGHT be too soon to say goodbye to poverty, but world governments are about to set a common agenda to do so – all while trying to save the planet.

At a UN summit in New York this week some 150 heads of state

“We have been talking about integration for two decades and here we have a set of goals that address it,” says Gisbert Glaser of the International Council for Science. He says the goals represent major progress on the Millennium Development Goals, established in 2000, which ignored wider environmental issues.

But for the goals to be reached, we will need financing for development to increase from “billions to trillions”, says David Griggs of the Monash Sustainability Institute, Australia.

“The development goals aim to eradicate poverty by 2030 and ensure a sustainable planet”

are set to endorse 17 sustainable development goals, such as to eradicate poverty by 2030 and to make cities sustainable.

Some say there are too many goals to be successful, and some of them lack rigour. Nevertheless, many scientists are cautiously rejoicing, because for the first time the targets include rescuing Earth's critical life support systems. Taken together, they say, the goals acknowledge the interconnectedness of things – that you can't have health and prosperity without taking the fragility of Earth's systems into account.

How to be happy

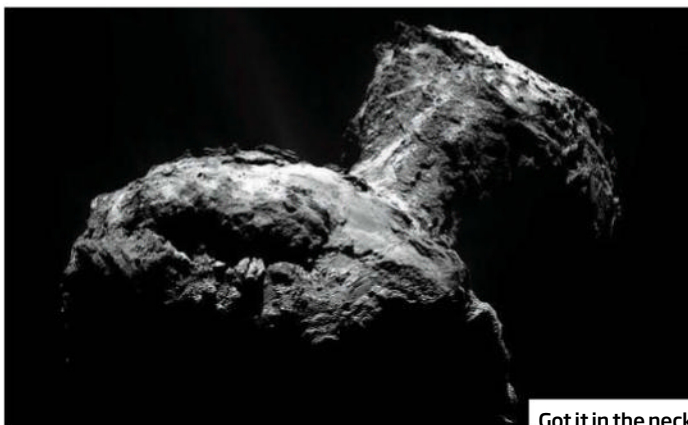
ARE you satisfied with life? The World Health Organization wants to know, and its first guinea pigs are the people in 53 European countries.

The WHO decided three years ago to try to include measures of well-being in its health assessments. It came up with five key measures. Four are objective, evaluating social connectedness, economic security, people's natural and built environments, and their education. The fifth – life satisfaction – is subjective.

In its *European Health Report 2015*, the WHO considers how to standardise measures of well-being across cultures that might have contrasting views on the value of material success or equality, for instance.

“All we've ever reported on has been death, disease and disability,” says Claudia Stein of the WHO. “Health is not just the absence of disease.”

The WHO is not abandoning traditional indicators of health. But by looking at how culture impacts health, it may be possible to make further improvements.



Got it in the neck

Icy forecast

#ROSETTAWATCH

EVEN comets have weather. The Rosetta space probe has spotted a square-kilometre field of solid ice in the neck region of comet 67P/Churyumov-Gerasimenko. The comet's day-night cycle drives its small weather system using the ice field, sublimating the ice into vapour when the sun rises.

The ice was spotted in data gathered last August using Rosetta's VIRTIS instrument –

a spectrometer designed to map the comet's chemical composition. The water signal was stronger when the neck was in shadow and weaker during the comet's day.

Most of the vapour is probably lost in space. The surface ice is likely to be replenished as water escapes from the comet's interior via cracks caused by the contrast in day and night temperatures.

Currently near the sun, the comet is sending out jets of ice and dust, and the team is holding the probe back to protect it. But as the mission has been extended to September 2016, the team should still be able to gather more data.

Listen up

WE ARE more than ready to hear the plucked strings of space-time. Last Friday, revamped LIGO took its first snaps – a step towards picking up the ripples that Einstein predicted should come from exotic cosmic collisions – our best opportunity so far.

During its original run from 2002 to 2010, the Laser Interferometer Gravitational-Wave Observatory listened for gravitational waves in a range that included about 100 galaxies. It didn't find any, probably because the main event it was searching for – the death spiral of two neutron stars – might only happen in a single galaxy once every 30,000 years.

The new experiment, Advanced LIGO, uses stronger lasers and better mirrors in two detectors based in Hanford, Washington, and Livingston, Louisiana. It will hopefully reach a volume of space that includes roughly 300,000 galaxies, and will be able to hear neutron star clashes on a monthly basis. But it will take some ramping up before Advanced LIGO is that sensitive.

"You don't turn on these things like a light and have them just work," says Matthew Evans of the Massachusetts Institute of Technology.

US nuclear slip-up

IT'S the kind of stuff you'd want to keep strict tabs on. Yet in July, the Y-12 National Security Complex in Oak Ridge, Tennessee, despatched more uranium to a private company within the US than it meant to, it now admits.

This was caused by human error, says Steven Wyatt of the National Nuclear Security Administration, which manages the Y-12 site.

Contractors at the unnamed firm reported the overgenerous delivery, prompting Y-12 – a nuclear weapons facility – to put

the mistake right. "All material shipped... was recovered by a Y-12 team and returned to the Oak Ridge site safely," says Wyatt. "At no time was there risk to employees, the public, or the environment."

"These things shouldn't happen," says Robert Alvarez of the Institute for Policy Studies, a think tank in Washington DC. Alvarez has previously criticised security and safety at Y-12.

"Keeping track of highly enriched uranium is on their shortlist of priorities. That's on their basic, elemental list of functions," he says.

US faces government shutdown

HERE we go again. The US government could shut down this week, as it did in 2013, over a failure to agree a budget for operations. This time the issue is the government's funding of Planned Parenthood, a non-profit organisation that provides women's health services, including abortions.

The trouble started in July, when a Californian anti-abortion group released a series of videos in which people posed as company representatives wanting to obtain fetal tissue for scientific research. They secretly filmed meetings with Planned Parenthood executives, discussing the details involved in collecting and delivering the tissue.

Anti-abortion activists say the

videos show that Planned Parenthood will sell fetal remains for profit, which is illegal. Supporters of Planned Parenthood counter that the videos are edited deceptively and that reimbursement for handling and shipping the tissue is standard in the medical field.

Republicans in Congress launched an investigation in July, and a number of states followed suit. Last month, the first investigations to report findings concluded that Planned Parenthood complies with state laws and regulations.

Some Republicans have vowed not to vote for any budget that includes funding for Planned Parenthood, while Democrats have promised to protect its funding.

LEAH HOUSTON/THE SALT LAKE TRIBUNE VIA AP



Planned Parenthood funding at risk

60 SECONDS

Wildcat FIV woes

With fewer than 100 remaining in the Scottish highlands, the UK's last surviving wildcats (*Felis silvestris*) now face a new peril – the cat form of HIV. Vets at the University of Edinburgh have found the feline immunodeficiency virus in 23 feral and hybrid cats from around Scotland, including in Morvern, a priority wildcat conservation area.

Doomsday help

The Arctic doomsday seed vault has dispensed its first seeds. Opened on the Norwegian Svalbard archipelago in 2008 to protect crops from disease or nuclear war, it is sending wheat and barley seeds to replace those in a gene bank near Aleppo, Syria, that has been damaged by war.

Booming bugs

Antibiotic resistance is soaring in India, according to the first detailed data. In 2009, 29 per cent of samples taken from people tested positive for MRSA, rising to 47 per cent last year, according to a report by the Center for Disease Dynamics, Economics & Policy. As India becomes more prosperous, it is thought more people are demanding antibiotics for minor infections.

Cholera alert

At least six people in Iraq have died of cholera, with 70 diagnosed with the infection. The outbreak emerged last week just west of Baghdad. Iraq's minister of health said that the number of cases is expected to increase, although it is working with the World Health Organization and others to manage the outbreak.

Orbital warning

Space is hard. Commercial space firm Orbital Sciences lost a spacecraft full of cargo headed for the International Space Station in an explosion last October. The company wants to send four flights to the ISS by the end of 2016. But a NASA report last week warns that the firm's upgrades might not meet that timeline.

Virtual woman built from slices

The world's most detailed digital human is now online, writes **Jessica Hamzelou**

SHE died two decades ago, but her body lives on in digital form. An American woman's cadaver has been sliced more than 5000 times to create the world's most detailed digital body. The "human phantom" is available online and will make it possible to perform experiments no live human could undergo.

Not much is known about the woman, not even her name. All we know is that she was obese and died of heart disease at the age of 59 somewhere in Maryland. Her husband gave permission for her body to be used by the Visible Human Project, set up by the US National Library of Medicine in Bethesda, Maryland.

The original aim of the project was to provide digital subjects for medical education, but researchers have since begun to appreciate their potential for modelling dangerous experiments.

When the project began, the bodies of two people, a woman and a man, were imaged extensively using MRI and CT scanning. They were then frozen,

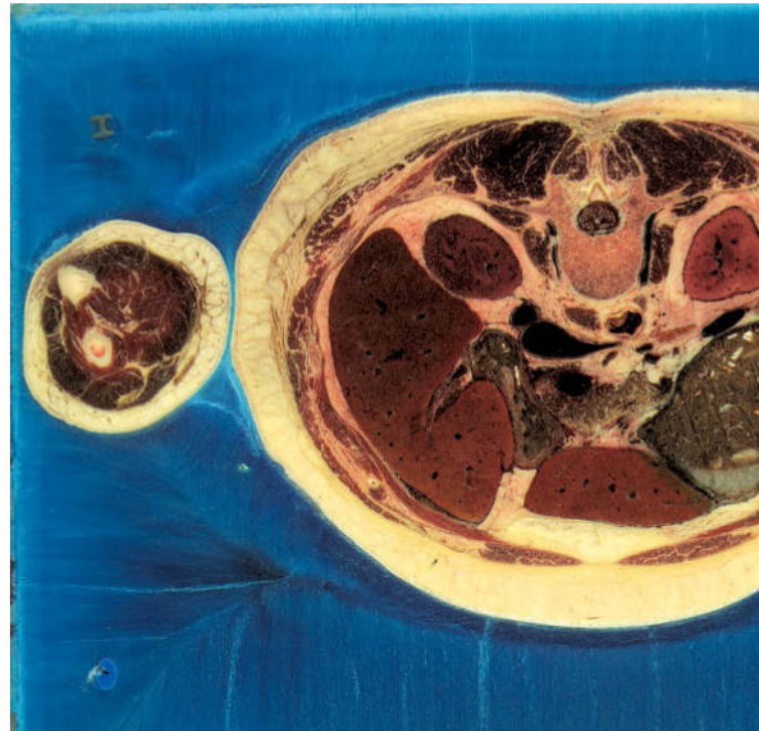
thinly sliced and photographed. The first photos were released back in the 1990s, and have been accessed thousands of times for research. Many teams have also pieced together digital versions of the man's body (see "Digital Frankenstein", below).

Now the woman's body has

"It took a lot of work, but now anyone can run an experiment on the phantom on their laptop"

been recreated, in far greater detail. She has been digitised at a much higher resolution, thanks to the thinner slices used. The male cadaver was sectioned at 1 millimetre intervals; the woman at intervals of just a third of a millimetre.

The virtual body is the work of Sergey Makarov at the Worcester Polytechnic Institute in Massachusetts and his colleagues. They used software to help them stitch the thousands of images together, and the final model was checked by five doctors, each with



a different medical specialism. "It needs to be anatomically correct," says Makarov, who presented the work at the IEEE Engineering in Medicine and Biology Society meeting in Milan, Italy, last month.

Their phantom is the most detailed digital reconstruction of a whole human body ever to be pieced together. She has 231 tissue parts, ranging from windpipe to eyeballs, but is missing nose cartilage and 14 other bits of the body.

Other teams have created phantoms from MRI and CT scans

of living volunteers, but the resolution is nowhere near as good. Entire body scans take several hours and any slight movements blur the image. The scans also lack colour, which is important for understanding different tissues, says Makarov.

"Sectioned colour images allow you to distinguish virtually all the anatomical structures we are made of," says Silvia Farcito at the Foundation for Research on Information Technologies in Society, based in Zurich, Switzerland, although she says that blood vessels tend to collapse in cadavers.

"They have ten times as much information as you'd get from an MRI scan," says Fernando Bello, who develops simulations for medical procedures at Imperial College London. "It means the team will have much more information about organs and their structuring."

The high resolution of the model makes it ideal for virtual experiments. Each of the woman's tissues has a well-defined set of parameters, such as density and

using scans of living volunteers.

For example, Paul Segars at Duke University in Durham, North Carolina, used MRI scans to replace some of the missing parts. "I ended up replacing both testicles and the penis so everything matched," he says.

Segars also replaced Jernigan's brain, which he said looked abnormally swollen. The result is a patchwork, almost like Frankenstein's monster, he says.

DIGITAL FRANKENSTEIN

The project to build fully digitised human bodies was launched in the mid-1980s. Except for a few missing pieces (see main story), the female virtual model is now complete, but her male counterpart was finished years ago.

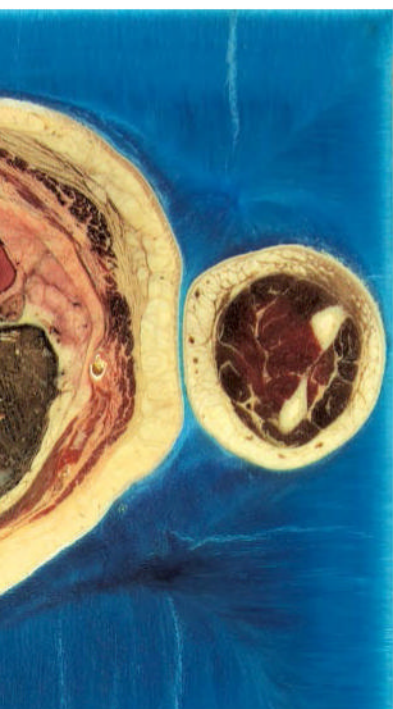
The body it was based on was that of Joseph Paul Jernigan, a 39-year-old Texan convicted of murder and put to death by lethal injection. Digital versions of his

body were announced in 2010, but ethical questions over using his data remain. Although it is reported that Jernigan willingly donated his body to science, he probably could not have known the extent to which it would be used and circulated.

His body was also missing several pieces. When he died, Jernigan was short of an appendix, a testicle and several teeth. These body parts have since been added

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VISIBLE HUMAN PROJECT

It's what's inside that counts

thermal conductivity. This makes it possible to compute the impact that radiation, for example, and various imaging techniques are likely to have on living tissues.

"The phantom gives us a great opportunity to study human tissues without having to do human studies, which are lengthy and expensive," says Ara Nazarian, an orthopaedic surgeon at Harvard Medical School who is collaborating with Makarov.

Ideal test subject

Makarov's team has already started running tests that are too risky to try on living people. In one, they gave their model a metal hip or femur, and studied the effect of putting it in an MRI scanner. Metal implants heat up in the scanner's strong magnetic field, and little is known at present about how best to scan people who have them.

The researchers were able to test what happens at different strengths of magnetic field, and feed their results back to clinical staff. Doctors may be able to use

their data to develop safer, more effective scanning procedures for people with implants.

Having a female phantom allows us to better investigate diseases that more commonly affect women, Makarov says. He hopes to improve breast cancer screening, for example, to give more reliable mammogram results.

He is also testing the effect of long-term cellphone use on the brain, and assessing the safety of a brain stimulation technique called transcranial direct current stimulation (tDCS), which is being developed as a possible treatment for a range of conditions, including depression, dementia, schizophrenia and chronic pain. "We have a pretty good model of the brain, encased in a shell of cerebrospinal fluid," says Makarov.

Early results suggest that tDCS might create larger electrical currents when it is used more deeply in the brain and in white matter, which could have implications for how it is applied and whether it is safe. Makarov points out, though, that although his team is running the experiments, it will be down to people with specialist knowledge to interpret the findings.

The Maryland woman's obesity makes her particularly relevant, Makarov says, given the high levels of obesity in many countries today. But because the phantom is fully digital, the researchers have also been able to create two thinner versions, with less skin and fat.

The team have made the model freely available, and it can be modified using basic software already used in labs all over the world. "Creating the phantom took a lot of work, but now anyone can run an experiment on their laptop," says Nazarian.

This means the virtual woman can be put through endless tests worldwide. "There are lots of possible uses," says Bello. "It is really exciting." ■

Chimpanzees anticipate exciting parts of a movie

WE ALL have our favourite movie moments, ones we love to watch again from time to time. Now it seems chimpanzees and bonobos also have the smarts to recall thrilling scenes.

The findings suggest apes can recall and anticipate significant recent events – something that may help them avoid danger and manage complex social situations in the wild.

Fumihiro Kano and Satoshi Hirata of Kyoto University in Japan wrote and starred in two 30-second-long films they showed to apes on two consecutive days. A third character was a human wearing a King Kong costume. Both films were designed to contain memorable dramatic events, and the researchers deployed laser eye-tracking technology to see whether the animals preferentially noticed and remembered these moments. "In our previous studies we found that apes seem to remember emotional events rather than neutral ones, just like humans do," says Kano.

In the first movie, the ape character bursts in through the door on the right – one of two visible on screen – and attacks one of the two people. Through tracking the gaze of six chimpanzees and six bonobos, the pair found that on the second viewing, most animals preferentially looked at the right-hand doorway 3 seconds before the ape burst in, showing

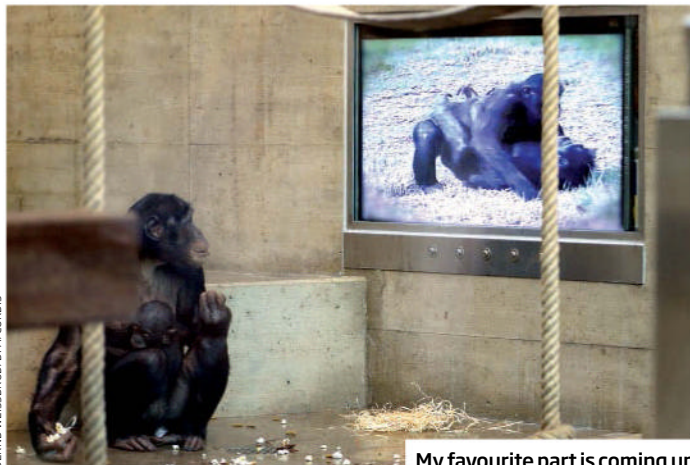
recall of locational content.

The second movie allowed the team to show that the apes could also remember which items were relevant to a plot. In the first screening, a human character chose one of two adjacent weapons to launch a revenge attack on the ape. The second screening used a slightly different version that swapped the positions

"The fact that the apes remembered such details from the previous video was really impressive"

of the weapons. Yet the animals focused their anticipatory glances on the weapon used in the first showing, demonstrating that they knew what it would be used for and their expectation that the character would select it again, even though it was in a different place (*Current Biology*, doi.org/7rz). "The fact they remembered such details from the previous video was really impressive," says Kano.

Laurie Santos of Yale University says the study shows that apes not only have memories of specific events but are able to track some of the emotions associated with those events. The team now plans to use similar films to probe whether apes understand other beings' goals, intentions and beliefs. ■



BERND WEISSBROD/DPA/CORBIS

My favourite part is coming up

FIELD NOTES Antikythera, Greece



Vacuums - also handy underwater

Diving for pearls of Greek wisdom

Jo Marchant

GEMMA SMITH is grinning like a child on Christmas morning. "It could be anything!" she says as our boat speeds past the rugged grey cliffs of Antikythera, a tiny Greek island midway between the Peloponnese and Crete. We are here to explore one of the world's most famous shipwrecks, where divers once found an ancient computer.

The day before, the team discovered part of a large object buried beneath a metre of sand; now they are back to find out what it is. After years of preparation, there's a feeling that today is going to be big.

The ship that sank here was a hefty wooden vessel, sailing west from Asia Minor towards Rome

when it smashed against the island's cliffs in the 1st century BC. It was discovered in 1900 by sponge divers, who salvaged the site under the direction of Greek archaeologists: the first scientific investigation of a shipwreck. They found bronze and marble statues, gold jewellery, ornate furniture, and gorgeous ceramics and glassware. Most intriguing was an ancient geared device – the Antikythera mechanism. Now understood to have been a clockwork computer, it was used to predict and display the movements of the sun, moon and planets in the sky (see "The solar system in a box", opposite). "It is a symbolic place," says Theotokis Theodoulou, an archaeologist at Greece's Ephorate of Underwater Antiquities. "This is the cradle of

underwater archaeology."

In 1976, a scuba team led by marine explorer Jacques Cousteau excavated a small area of the site and brought up hundreds of small items including jewellery, statuettes and coins, suggesting that much of the ship's cargo still lies buried under the sand.

Now, an international team has come to finish the job. They hope to uncover more exquisite

statues, or even other examples of advanced technology. It is possible that the ship contained several geared devices, particularly if it was carrying a commercial consignment rather than stolen loot, speculates Michael Wright, a London-based mechanic and curator. "I live in hope!" he says.

The project is led by Theodoulou, his colleague Dimitris Kourkouvelis at the Ephorate of Underwater Antiquities and Brendan Foley, an archaeologist at Woods Hole Oceanographic Institution in Massachusetts. The \$1.8 million scheme, funded largely by private and corporate sponsors, is one of biggest underwater archaeology efforts in world, and dwarfs those carried out before in Greece.

There are two main challenges. Few archaeologists are qualified to dive to the site's 55 metres, where the risk of the bends is severe. So to avoid injury, they descend with dive specialists including Smith, and only dive for

Underwater riches

A shipwreck that held an ancient Greek computer, and might yield many more treasures, sits 55 metres below the sea surface near the island of Antikythera



45 minutes at a time, taking 90 minutes to decompress.

Another problem is finding items hidden in the sand. Cousteau's 1976 team used a huge suction pipe to Hoover up the seabed, dumping sediment and precious artefacts onto the deck of their ship. But the priority now is to record and understand the site, not simply to salvage its treasure.

So in June, Foley and a team from the University of Sydney in Australia used stereoscopic cameras and sonar mounted on an underwater drone to make a 3D map of the site.

Reconstruction site

Then, at the end of August, the dive team arrived on this windswept island. Its members surveyed the site with handheld metal detectors, investigating hits by fanning water with their hands to dig shallow trenches, and sucking away the raised sediment with a small dredge. They marked any finds directly onto the 3D map as they worked, using an iPad in a waterproof case.

While underwater, the researchers also took hundreds of photographs from different angles of artefacts and of an excavation trench. Software then crunched these into a 3D virtual reconstruction.

Such software is changing the way underwater archaeology is done, says team member Brett Seymour, an underwater photographer for the US National Park Service. It allows researchers to map sites quickly and accurately instead of spending days with tape measures and drawing objects by hand.

"This site is inherently remote and difficult to access," adds Foley. "But through virtual reality and 3D modelling we can make it accessible for any archaeologist anywhere in the world."

The first couple of weeks of the diving expedition yielded a slow stream of finds including ship components such as roof tiles and

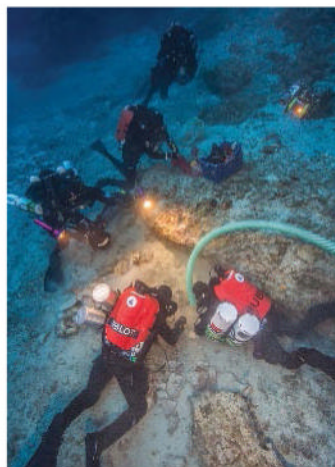
lead hull sheeting as well as finer items: sections of a bone flute, a blue game pawn and a statuette base. "These are prestige goods," says Foley, "not the sort of thing you normally find on a wreck."

Everyone was hoping for a headline-grabbing find, however, and on 8 September a shoebox-sized block of black metal, weighing nearly 30 kilograms, caused excitement. It was immediately dubbed the ship's "black box". But the metal turned out to be iron, probably a ballast weight dropped by Cousteau's diving saucer.

A couple of days later, diver Alexandros Sotiriou uncovered the square end of a large object buried deep in the sand. He was unable to move it, but believed he saw the green glint of semi-precious bronze.

Now, as the team reaches the wreck site to investigate Sotiriou's find, the excitement is palpable. As the first two divers descend, their colleagues and I crowd round a small screen on the boat, which shows a live video feed of progress underwater.

The divers wedge their scooter against a rock and use its propeller to create a water jet that pushes sand away. The pair disappear into a cloud of sediment, and later emerge with two long bars, each with a semicircular hole halfway down its length. The bars turn out to be lead, not bronze;



THE SOLAR SYSTEM IN A BOX

From one of the most famous shipwrecks came the most unlikely of finds (see main story). In the 1st century BC, a ship sunk off the coast of the island of Antikythera. Among the treasures salvaged from it in a 1900-1901 expedition was a battered lump of bronze, which cracked open to reveal gearwheels, pointers and inscriptions in ancient Greek.

Experts at the time were stumped, but decades of research, including X-ray analyses and CT scans, have revealed that the device was a clockwork computer, with more than 30 gearwheels that modelled the workings of the solar system.

This gearing was originally inside a wooden box, about the size of a

mantelpiece clock, with a handle that allowed the user to move forwards or backwards in time. Revolving pointers showed the movements of the sun, moon and planets, while a series of smaller dials displayed the timing of eclipses, and even the Olympic games.

Nothing close to its complexity appears again in the historical record for well over 1000 years. The device recast our understanding of ancient technology, and indicated that geared mechanisms – which led to the invention of modern clocks and the automated machinery that drove the industrial revolution – began not in Medieval Europe, but more than 2000 years ago in Greece.

the components of a large anchor. The team is quiet on the way back to harbour – this isn't what the divers had hoped for. But it's still a significant find, showing how deep the team must dig for larger items, and pinpointing the position of the ship's bow. With the stern already located, Foley and Theodoulou calculate the vessel's midpoint – a flat, featureless area dubbed "the meadow" – as the

"It is possible that the ship contained several geared devices like the Antikythera mechanism"

most likely place for its cargo.

The next day, Smith and Foley dig two 70-centimetre-deep trenches in the meadow. They surface jubilant. Within half an hour, they have uncovered several items, including a part of an amphora and an elegant wine jug. Smith's pockets are filled with small bronze pieces – nails, and what might be parts of a cooking pot. "There's obviously stuff down there," she says. "We just weren't digging deep enough before." It's the best dive of the project and Foley is convinced the team is about to reach the ship's cargo. "That's the way to go," he says. "Now it's just a matter of time."

But at this treacherous site, the project is at the mercy of the elements. The unrelenting north wind makes it too dangerous to dive again, and the divers pack for home, where they will collaborate with other teams to run tests on the recovered artefacts. Lead isotope analysis could reveal the ship's geographic origin, and DNA analysis could shed light on the make-up of ancient products.

But to discover if the wreck hides the treasures they dream of, perhaps even another ancient computer, they must wait for next year's expedition. ■



The wreck that keeps on giving

Grains of gold shine at computing

Bas den Hond

MOVE over, microchip. A random assembly of gold nanoparticles can perform calculations normally reserved for neatly arranged patterns of silicon.

Traditional computers rely on ordered circuits that follow preprogrammed rules, but this limits their efficiency. "The best microprocessors you can buy in a store now can do 10^{11} operations per second, and use a few hundred watts," says Wilfred van der Wiel of the University of Twente in the Netherlands. "The human brain can do orders of magnitude more and uses only 10 to 20 watts. That's a huge gap."

To close that gap, researchers have tried building "brain-like" computers that can do calculations even though their circuitry was not specifically designed to do so. But no one had made one that could reliably perform calculations.

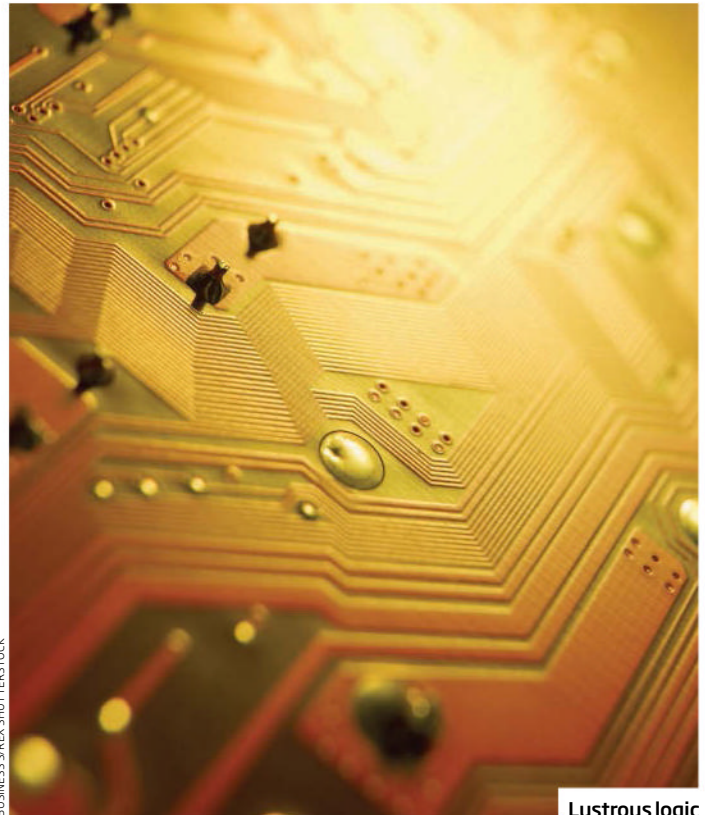
Van der Wiel and his colleagues have hit the jackpot, using gold particles about 20 nanometres across. They laid a few tens of these grains in a rough heap, with each one about 1 nanometre from its

nearest neighbours, and placed eight electrodes around them.

When they applied just the right voltages to the cluster at six specific locations, the gold behaved like a network of transistors – but without the strict sequence of connections in a regular microchip. The system not only performed calculations, but also used less energy than conventional circuitry.

Nothing about the particles told the researchers what voltages to try, however. They started with random values and learned which were the most useful using a genetic algorithm, a procedure that borrows ideas from Darwinian evolution to home in on the "fittest" ones.

The team was able to find voltages to transform the system into any one of the six "logic gates" that are the building blocks of computer chips. The algorithm even arrived at the combination for a higher-order logic unit, which can add two bits of information. "This shows that you can get to calculating ability by a completely different route," van der Wiel says (*Nature Nanotechnology*, doi.org/7s5).



Lustrous logic

The gold clump has to be cooled to just 0.3°C above absolute zero, but making the grains even smaller would allow the working temperature to rise. Van der Wiel says there is no reason the approach couldn't work at room temperature.

"The physics is there, but of course you still have to demonstrate it," says Jie Han

of the University of Alberta in Edmonton, Canada.

Van der Wiel hopes the work will lead to specialised processors that can solve problems that are difficult for computers, such as pattern recognition. That's because the gold grains work in parallel – much like neurons in the human brain, which is especially good at these tasks. ■

We walk around in a cloud of our own microbes

HYGIENE obsessives – your worst fears have been confirmed. Everyone walks around enveloped in an airborne cloud of bacteria, a bit like the *Peanuts* character Pig-Pen, and some of the bugs come from our most intimate nooks and crannies.

"You are standing in another person's microbial cloud the moment you shake hands," says James Meadow

of the University of Oregon in Eugene.

Our bodies are home to an estimated 100 trillion bacteria, viruses and fungi. People leave traces of their microbial communities on surfaces like their phones, and Meadow's team wondered if the air around us also carries such signatures.

The group asked people to sit still in a small sterile room, and took samples from the air 1 metre away, and from the floor to catch falling bacteria. Analysing the bacterial DNA, the team found many species that usually live on the skin and in the mouth, nose and gut, and in the case of women,

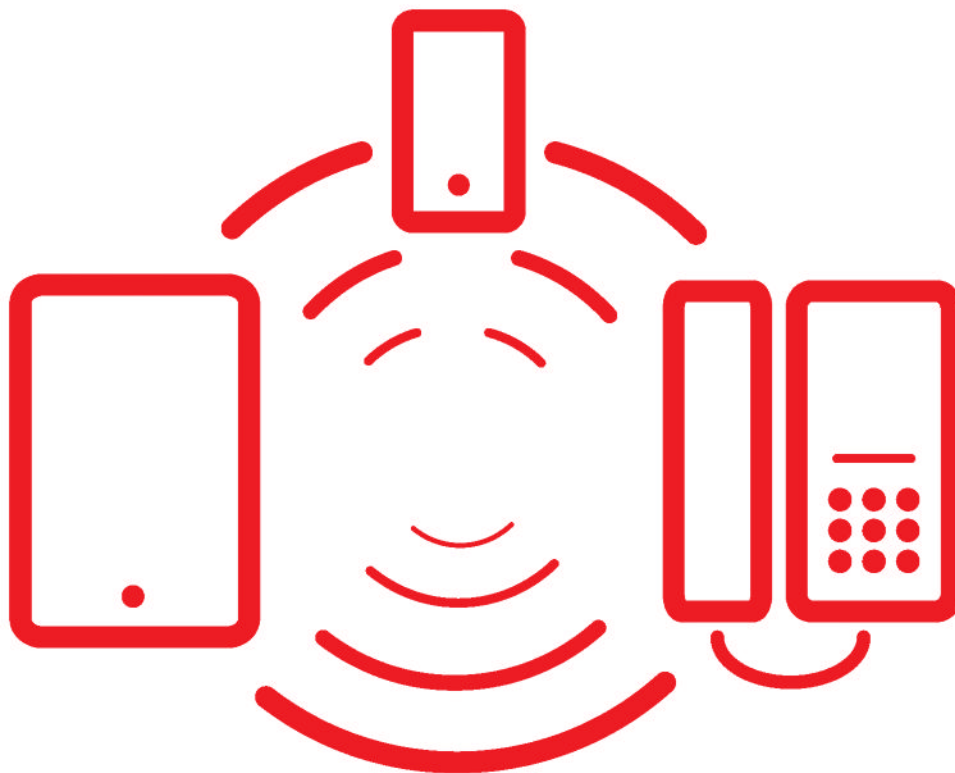
the vagina. Nine of the 11 people tested had distinct personalised signatures of bacteria combinations (*PeerJ*, DOI: 10.7717/peerj.1258).

It's possible that these clouds transmit disease. MRSA has been found living on the skin and noses of otherwise healthy people, so it could be in their clouds. Meadow suspects that respiratory viruses such as measles probably are too.

"In the future we could be recognising crime suspects by the bacterial mist they leave behind"

The results could have a forensic use, helping to place a suspect at a crime scene through their bacterial signature. "I don't think it's crazy to think that, in the future, we could be recognising people by their bacterial mist," says Tim Spector of King's College London.

But Meadow says the findings are just a first step. Volunteers in the study sat in the room for up to 4 hours, but in reality someone may spend only moments at a crime scene, and it would probably already be contaminated with the bugs of many other people. Clare Wilson ■



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Wasp uses virus to make GM butterfly

Michael Le Page

IF YOU thought genetic modification was just something humans did, think again. A French team has found that the iconic monarch butterfly, famed for its long migrations, has wasp genes in its genome.

The monarch is not alone. Wasp genes have been found in several butterfly and moth species, inserted by viruses that the wasps use as biological weapons.

There are numerous species of parasitic wasp that lay their eggs in caterpillars. When the larvae hatch they feed on the caterpillar's body, and the wasps have evolved a truly extraordinary way of subduing the caterpillar's immune system to stop it attacking their offspring.

The female produces millions of virus-like particles in its ovaries and injects these into the caterpillar along with an egg. The viruses invade almost every type of cell in the caterpillar's body, and their DNA gets integrated into its genome. Normal viruses carry genes for the proteins they need to replicate. But bracoviruses, as they are called, are different. They

carry genes, some of which come originally from the wasp, that turn off the caterpillar's immune defences and render it helpless against the wasp larva.

Bracoviruses can no longer replicate themselves: instead, the genes for making them have become incorporated into the wasp genome, a discovery made in 2009 by a team led by Jean-Michel Drezen, now at François Rabelais University in Tours, France.

In other words, over the past

100 million years, wasps have tamed once free-living viruses and turned them into sophisticated biological weapons. There are now thousands of species of braconid wasp, each of which lays eggs in a specific butterfly or moth species and produces a unique bracovirus.

Sometimes, though, a wasp lays an egg in the wrong host, in which case its larva may not survive. But the bracoviruses still get into the caterpillar, and can find their way into the genome of developing egg or sperm cells. They will then be passed down to the insect's offspring and can become a permanent part of its genome.

Drezen's team has now shown that this has happened on several

occasions. Along with the monarch butterfly, they have found DNA derived from wasps in silkworms and two kinds of armyworm moth (*PLoS Genetics*, doi.org/7r2). This is just the tip of the iceberg, Drezen thinks.

But is this really evidence of "naturally occurring GM butterflies", as Drezen's team claims? In the widest sense of the term, every organism is genetically altered, as random mutations in our cells happen throughout our lives.

By genetically modified, though, Drezen is really saying that the butterflies are transgenic: meaning they have acquired genes from completely different species. Much of the opposition to transgenic crops and animals stems from the idea that this kind of interspecies gene swapping is unnatural and dangerous.

But it has turned out to be widespread in nature. The sweet potato acquired DNA from a gene-meddling bacterium as recently as 10,000 years ago, and even humans have acquired dozens of genes this way in just the past few million years.

So even in the more limited transgenic sense, just about every organism can still be described as genetically modified. "I must confess I can't say that is not true," Drezen says. The description was a way to attract interest, he admits. "And it's worked." ■



INGO ARNDT/NATUREPL.COM

Naturally transgenic

Bionic pancreas automatically controls insulin

SENSOR, pump, action! An app linked to a glucose sensor and insulin pump can make life a lot easier for people with type 1 diabetes.

"The sense of potential freedom is amazing," says Juliet Hughes, mother of 8-year-old Felix, who took part in a trial to see if a bionic pancreas could free diabetics from the daily routine of monitoring and regulating their

glucose levels (*New England Journal of Medicine*, doi.org/7s4).

Type 1 diabetes is caused by destruction of beta cells in the pancreas that make insulin to control how much sugar circulates in the blood. When the pancreas is no longer in control, a person risks coma and death from plunging glucose levels.

A glucose sensor and insulin pump, both attached to the abdomen, are used by some people with type 1 diabetes to manage their condition, but they still have to check their glucose levels themselves, and adjust their insulin intake manually.

The bionic pancreas does this job itself, using an algorithm on a tablet computer or a phone to monitor a person's blood glucose. When levels rise, for example after a meal, the algorithm automatically sends instructions to the insulin pump.

"It tells the pump how much insulin to deliver and it does it day and night," says Roman Hovorka of the University of Cambridge. This means there is no

need to wake up to check blood sugar levels throughout the night.

To see if their bionic pancreas really would improve quality of life, Hovorka's team ran a three-month trial involving 33 adults and 25 children. Compared with a sensor and pump without an algorithm, children using the bionic device spent half as much time with seriously low sugar levels, just 5 minutes a night.

"It took time to trust the system, but once we did, and saw the amazing results, it meant a lot more sleep for everyone," says Hughes. Andy Coghlan ■

"Once we trusted the system's amazing results, it meant a lot more sleep for everyone"

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Who's telling tall tales about nocturnal giraffe noises?

LIONS roar, elephants trumpet – but what do giraffes do?

Biologists have speculated for years about whether giraffes can vocalise, or whether their long necks prevent them from producing the necessary airflow.

After reviewing almost 1000 hours of sound recordings from three European zoos, Angela Stöger at the University of Vienna, Austria, has an answer.

Her microphones picked up a low hum from the giraffe enclosures at night. At about 92 hertz, the sound is just within the lower limit of human hearing (*BMC Research Notes*, doi.org/7rt). Giraffes have a structured social

system, and for a long time scientists have been trying to figure out how they communicate, says Meredith Bashaw at Franklin & Marshall College in Lancaster, Pennsylvania.

"This new vocalisation could add a piece to that puzzle," she says.

The recordings might come as no surprise to the residents of Paignton in Devon, UK. Last year some of them complained of a humming or droning noise coming from Paignton Zoo's giraffe house at night.

However, despite the new findings, Paignton Zoo denies any giraffe involvement. "No, definitely not linked to our neighbours' issue – but the image of our giraffes humming happily to themselves all night is a delightful one," says Phil Knowling, press and public relations officer at Paignton Zoo.

Weak waves can trigger strong quakes

SEISMIC waves unleashed during this month's magnitude 8.3 quake in Chile could have triggered aftershocks 1000 kilometres away – and a model explains how.

We know that major quakes, like 1992's Landers earthquake in California, can send out seismic waves that spark large tremors far away – even though the waves get weaker as they travel.

"We were wondering: how could

a very tiny wave with a very small amplitude trigger earthquakes 1000 kilometres away?" asks Lucilla de Arcangelis of the Second University of Naples in Italy.

One idea is that acoustic vibrations from the initial quake lather up the ground-up rock in a geological fault in a way that decreases friction. This then makes the fault more likely to slip and an earthquake to occur. Now

a team including de Arcangelis has built a computer model that shows this process as it happens.

They found that seismic waves could trigger an earthquake in the simulated fault only if they came in a narrow range of frequencies. If the fault was just about to slip, the waves would hasten the process by starting acoustic vibrations in that range. Only the frequency mattered – even weak waves could induce a quake (*Physical Review Letters*, doi.

Bladder control helps you tell lies

OVERCOOKED your CV? Drink a large coffee before going into the job interview: people seem to lie more convincingly when they are suppressing the urge to urinate.

Iris Blandón-Gitlin of California State University in Fullerton and her colleagues asked students to complete a questionnaire on controversial issues. They were then interviewed by a panel, but instructed to lie about their opinions on two issues.

Before the interviews began, half the students drank 700 millilitres of water. The other half drank 50 ml.

The interviewers detected lies less frequently among those with a full bladder (*Consciousness and Cognition*, doi.org/7rx).

The findings build on earlier work suggesting that different activities requiring self-control share common mechanisms in the brain, and engaging in one type of control enhances another.

Wasps sever heads in brutal fig war

KILL first, ask questions later – if you're a wasp living inside a fig.

James Cook of the University of Reading, UK, and his colleagues found that some male fig wasps go on the rampage when looking for a mate, often decapitating males from different species, as well as beheading rival males from their own species.

Fighting to the death is not normal behaviour in the animal kingdom – but circumstances in the figs are unusual. Male wasps live only a few days, and females are rare. It makes sense for males to move fast and risk their lives for an opportunity to mate – even if that means fighting before they identify whether their opponent is a genuine rival (*Ecological Entomology*, doi.org/7rj).

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Dig that octopus disappearing trick

NOW you see it, now you don't. The southern sand octopus (*Octopus kaurua*) disappears under the sea floor by shooting jets of water that create quicksand beneath it.

A skilled architect, the octopus can then build a mucus-lined home – complete with a “chimney” – 20 centimetres under the surface, where it holes up during the day. It only emerges at night, to feed on small crustaceans.

Other octopuses, including the southern keeled octopus, bury themselves under a thin layer of sediment by digging with sweeping arm movements. But because they need direct access to the water to get oxygen, they remain close to the surface, using their tube-like funnels to respire.

The sand octopus has a very different technique, digging deeper and using its hideaway's chimney to access water.

“This is the first cephalopod known to burrow,” says Jasper Montana of the University of Melbourne, Australia.

Montana and his team suspect that the octopus evolved its building acumen to avoid predators. Unlike many octopus species, it lacks camouflage abilities. Its thin arms may have evolved to reach worms and crustaceans in narrow burrows under the sand, Montana adds (*Behaviour*, doi.org/7rw).



Brain stimulation alters our desire to punish wrongdoers

HOW would you punish a murderer? Your answer will depend on how active a certain part of your brain happens to be.

Joshua Buckholz at the University of Harvard and his colleagues gave 66 volunteers scenarios involving a fictitious criminal called John. Some of his crimes were planned. In others, he was experiencing psychosis or distress – for example, his daughter's life under threat. The volunteers had to decide how responsible John was for each crime and the severity of his

punishment on a scale of 0 to 9.

Before hearing the stories, some of the volunteers received magnetic stimulation to a brain region involved in decision-making, called the dorsolateral prefrontal cortex (DLPFC), which dampened its activity. The others were given a sham treatment.

Inhibiting the DLPFC didn't affect how responsible the volunteers thought John was for the crimes, or the punishment he should receive when he was not culpable for his actions. But they meted out a much less severe

punishment than the control group when John had planned his crime (*Neuron*, doi.org/7rh).

“By altering one process in the brain, we can alter our judgements,” says Christian Ruff at the Swiss Federal Institute of Technology in Zurich.

In the justice system, the judgment stage to determine guilt is separated from sentencing, says James Tabery at the University of Utah. “It turns out that our brains work in a similar fashion.” See page 36 for more on our morality

Citizen scientists spot comet cloud

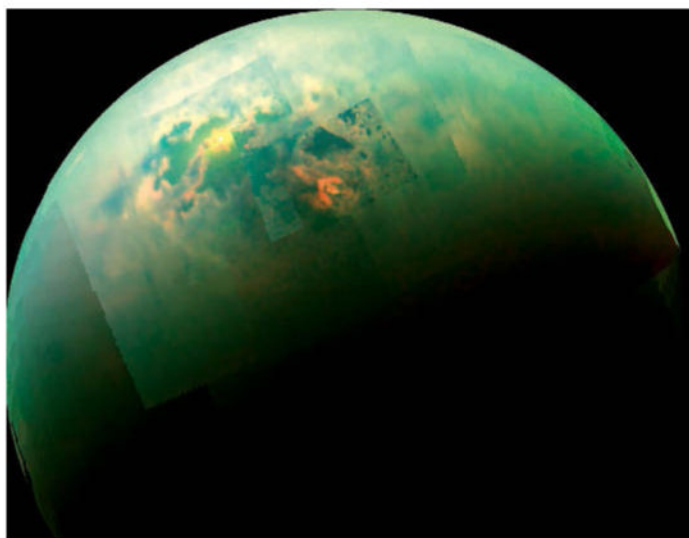
THE Planet Hunters have made a discovery – and it's not a planet.

Citizen scientists with a yen for astronomical detective work can log on to the Planet Hunters website to manually check data collected by NASA's Kepler space telescope for signs of exoplanets.

Orbiting planets block their stars' light for a few hours or days at regular intervals that correspond to the duration of their orbit. But planet hunters found that data from one star – KIC 8462852 – didn't follow this pattern. There were two small dips in 2009, and many during three months in 2013, for instance.

“We were scratching our heads,” says Tabetha Boyajian, an astronomer at Yale University. But now she and her colleagues have come up with an explanation. They think that a family of exocomets veered close to the star and were broken up by its gravity, producing huge amounts of dust and gas in the process.

If the comets are on an eccentric orbit passing in front of the star every 700 days or so, further breaking up and spreading out as they go, that could explain the data (arxiv.org/abs/1509.03622).



NASA/JPL-CALTECH/UNIV. ARIZONA/UNIV. IDAHO

Titan has sun-warmed swirling seas

AND now, the first alien shipping forecast. Solar-driven currents surge through the oceans on Titan, Saturn's largest moon.

Titan is the only place in the solar system, apart from Earth, that has large bodies of liquid on its surface, though its seas are composed of hydrocarbons such as methane rather than water.

Now researchers have simulated currents in the large seas at the moon's northern hemisphere. If Titan's seas aren't too murky, sunlight could carry heat into the deep sea and make the methane less

dense. The simulation predicts this would cause anticlockwise currents near the sea surface and clockwise currents near the bottom, creating gyres (*Icarus*, doi.org/7sz).

Water takes a lot of energy to heat, so sunlight shining on Earth only raises ocean temperatures near the surface. But on Titan, solar-driven currents could be substantial, says Ralph Lorenz at Johns Hopkins University in Baltimore, Maryland.

If submarines are ever sent to Titan, they would need to be supplied with enough power to navigate the methane currents.



Trees or broccoli?

Beyond Turing

When **Jacob Aron** judged an artificial intelligence challenge, the contestants did not interview well. So how best to put bots to the test?

LAST Saturday I took part in a battle of wits at Bletchley Park, the stately home that housed the UK's codebreakers during the second world war. I was a judge in the annual Loebner prize competition, held to determine whether computers can think just like a human. It probably won't surprise you that they can't, but machines are increasingly giving us a run for our money at certain tasks.

Bletchley is a fitting arena: the competition is based on a test proposed by mathematician and computing pioneer Alan Turing, who spent the war there cracking Nazi codes. He argued that if a computer could fool a person into believing it was human, it could think.

With the Loebner prize, four

human judges each sit at a computer and carry out two text-based conversations at the same time – one with a real person hidden in a separate room, the other with a chatbot. The judges have 25 minutes to figure out which is which, before moving on to another human/AI pair.

In practice I needed just minutes to tell human from machine. One bot began with the novel strategy of bribing me to split the prize money if I declared it human, while another claimed to be an alien on a spaceship. These tactics didn't work. The humans quickly made themselves known by answering simple questions about the weather or surroundings, which the bots either ignored or got hopelessly wrong.

In the end none of the four bots fooled any of the judges, and, as with every other contest in the history of the Loebner prize, the best performer only earned a bronze medal. So are we any nearer to a true artificial intelligence?

One problem with the Turing test is that no one can quite agree what counts as a pass. Turing, writing in the 1950s, predicted that by the 21st century it would be possible for computers to pass the test around 30 per cent of the time. Some have interpreted this as the percentage of judges a

"One bot bribed me to split the prize money, while another claimed to be an alien on a spaceship"

machine has to fool, leading to headlines last year claiming that a chatbot at the Royal Society in London had passed the test. Others see 50 per cent as a pass.

But even if one of the chatbots had managed to fool us all last week, that wouldn't really have told us anything about its intelligence. That's because the results of the test also depend on the judges' level of technical understanding and choice of questions, which will colour their ratings.

As a result, most AI researchers long ago abandoned the Turing test in favour of more reliable ways to put machines through their paces. In just the past couple of years, algorithms have started to match and even exceed human performance at tasks outside the realm of everyday conversation.

"I spend my time trying to get computers to understand the visual world rather than win a Turing test, because I think it's a quicker route to intelligence," says Erik Learned-Miller of the University of Massachusetts,

Amherst. He is one of the people behind the Labeled Faces in the Wild (LFW) data set. A collection of more than 13,000 facial images and names, taken from the web, it has become the de facto standard for testing facial recognition algorithms.

There have been vast improvements in this field thanks to hardware and software advances in deep learning and neural networks, AI techniques that attempt to mimic the neuron structure of the brain. Last year Facebook published details of its DeepFace algorithm, which scored 97.25 per cent accuracy on the LFW data set, just short of the human average of 97.5 per cent.

“When they got that, people realised this is the way to go,” says Learned-Miller. According to him, it kicked off an arms race between tech’s biggest names. This year Google’s FaceNet system hit 99.63 per cent – seemingly better than humans. That’s not quite the case, says Learned-Miller, as it’s hard to measure our performance accurately, but “machines are about comparable to humans”.

Big companies are also testing their algorithms on a data set called ImageNet, a more general collection of labelled images, and

vying to win the Large Scale Visual Recognition Challenge. In advance of this year’s contest, to be held in November, Microsoft has published details of its algorithm that scores a record-beating 95.6 per cent – again, just slightly ahead of humans on this task.

But one of the challenge’s organisers, Olga Russakovsky of Carnegie Mellon University (CMU) in Pittsburgh, Pennsylvania, points out that the algorithms

“Trying to get computers to understand the visual world is a quicker route to intelligence”

only have to identify images as belonging to one of a thousand categories. That’s tiny compared with what humans can achieve. “Even if you can recognise all objects, that’s very far from building an intelligent machine,” she says. To show true intelligence, machines will have to draw inferences about the wider context of an image and what might happen 1 second after a picture was taken, she says.

An altogether different task is allowing other bots to display abilities of this type. When humans have to make decisions

based on partial information, we try to infer what other people will do. Could an AI do the same? “Poker has become the benchmark for measuring intelligence in these incomplete information settings,” says Tuomas Sandholm, also at CMU.

The uncertainties of poker make it a much harder game for machines than chess, at which computers are now unbeatable. In January a team at the University of Alberta in Edmonton, Canada, published details of a poker bot that can beat any human, but only at a simpler form of the game.

In proper poker, humans still hold the edge, but only just. A few months ago, Sandholm pitted his bot against a team of poker pros. It lost by a slim margin. “At least 99.9 per cent of humans would be much worse than our program,” he says. This kind of tournament is an improvement over the Turing test, he says. “I like it a lot as a test, because it’s not about trying to fake AI. You really have to be intelligent to beat humans.”

Is there any life left in the Turing test? Bertie Müller of the Society for the Study of Artificial Intelligence and Simulation of Behaviour, which administers the Loebner prize, says the contest is held partly for tradition’s sake. Turing himself might not view it as the best test of intelligence were he alive today, he says. For Müller, a better test might be to observe an AI in a variety of environments – a bit like putting a toddler in a room full of toys and studying what it does.

“There has been a shift to trying to replicate these more fundamental abilities on which intelligence is built,” says Learned-Miller. All the researchers I spoke to agreed that a truly intelligent machine would have to be able to get a sense of the real world through computer vision, and not just be confined to a text-based interface. But we are a long, long way from putting all the pieces together to get a thinking machine. ■

ONE PER CENT



Lifesaver on your wrist

Compress chest 30 times, then give two rescue breaths. Repeat until the ambulance arrives. Cardiopulmonary resuscitation might not sound too complicated, but in the heat of the moment, a smartwatch app may help. Developed at the German Research Center for Artificial Intelligence, it uses the device’s sensors to guide chest compressions, significantly improving novices’ performance.

137.9 km/h

The new speed record for a pedal-driven vehicle, set at the World Human Powered Speed Challenge in Nevada last week

Built-in smokescreen

Half a million cars sold in the US have been telling lies. Last week, the US Environmental Protection Agency accused Volkswagen of cheating in emissions tests. The EPA claims that the software in certain Volkswagen models “detects when the car is undergoing official emissions testing, and turns full emissions controls on only during the test”. This hides the cars’ true emissions of nitrogen oxide. On Monday, Volkswagen’s CEO apologised and ordered an investigation.

BIRN SVENSSON/SUPERSTOCK

WHOSE AI IS TOP OF THE CLASS?

How best to put artificial intelligence to the test? Assessments straight out of the classroom are catching on.

In a study published last week, an AI system called ConceptNet tackled an IQ test designed for preschoolers, fielding questions like “Why do we wear sunscreen in summer?” Its results were on a par with the average 4-year-old (arxiv.org/abs/1509.03390). And last year, a system called To-Robo passed the English section of Japan’s national college entrance exam.

At the Allen Institute for Artificial Intelligence in Seattle, Washington, Peter Clark and colleagues are honing a program called Aristo by giving it New York state school science exams.

They are a great exercise, says Clark, requiring machines to do basic reasoning and handle questions they might not have seen before.

Not everyone is convinced. Ernest Davis, a computer scientist at New York University in New York City, points out that AI often struggles with what we would regard as common sense. From that viewpoint, ordinary exams might not be the best way to measure machines’ progress.

Instead, he suggests writing exams specifically for machines. The questions would be trivial for a human but too strange or obvious to be looked up online, such as: “Is it possible to fold a watermelon?”

Avia Rutkin

The web in a box

You can break off a piece of the internet and take it wherever you go

Aviva Rutkin

IF YOU were stranded on a desert island, what one website would you bring?

Any of them would be tough to pack, unless you have a gadget like a LibraryBox: a small, do-it-yourself web server. The box beams a Wi-Fi network to the surrounding area. Once someone connects, they can access any of the files or webpages hosted on that box – no internet connection required.

Jason Griffey, founder of LibraryBox, was inspired by an art project created at New York University in 2011. Housed inside a lunchbox, the PirateBox was created by a professor looking for an easy way to swap digital files with his students.

Griffey saw the potential it could have for people living in areas with damaged or unreliable internet infrastructure, or even no way of getting online at all.

Anyone, he says, could “break a little piece of the internet off and take it with them somewhere”.

For the past few years, Griffey has been refining the original open-source PirateBox code: simplifying the installation process, making the box more portable and expanding the hardware options. The new devices, renamed LibraryBoxes, now run on a handful of volts powered by a small solar panel.

“There are advantages to not being on the internet. It’s very difficult to control or censor the information”

Today, LibraryBoxes can be found in 37 countries around the world.

Educational institutions are among the most common users. One library in Queensland uses it to share media with people living in rural corners of Australia. Another box rides aboard the Story Sailboat, a seafaring library

that delivers books to hard-to-reach communities off the coast of California.

In the tropical archipelago of Fiji, only about one in 100 people have fixed broadband access. Last year, a team at the International Association of Aquatic and Marine Science Libraries and Information Centers dropped off LibraryBoxes filled with thousands of documents about fishing, aquaculture and marine science on two of the islands.

Information like that can be crucial for people looking to start their own business or fishery, says Joan Parker, who worked on the project. “These are technical documents that seem to be really important to folks out there in the trenches.” Her group next plans to deliver boxes to the Philippines, where many libraries were damaged by typhoons this year.

At three universities in South Africa, students are training to be clinical associates – a new kind of

healthcare worker who can diagnose and treat common ailments. Thanks to nearby LibraryBoxes, students can use their cellphones or tablets to check up on government guidelines, peruse an ebook or watch YouTube videos of medical procedures.

“The LibraryBox is a great way to be able to share resources. It creates that feeling of being online,” says John Capati, regional director for Southern Africa at the American International Healthcare Alliance.

Firewall breaker

Ultimately, there’s no way to know how many LibraryBoxes are in use. The project sells them for \$150 each, but anyone can download the source code for free and build their own at home. Since the box doesn’t connect to other networks, it could easily escape the notice of most people – even Griffey wouldn’t know it was out there.

“This is a feature and not a bug,” says Griffey. “There are advantages to not being on the internet. It’s very difficult to control or censor the information that’s being shared.”

In fact, he says, a few people in countries with strict government firewalls have found the box a valuable way to quietly share documents that are otherwise blocked.

LibraryBox isn’t the first to try building hyperlocal web servers. For example, during Occupy Wall Street, developer Dan Phiffer created a similar project called occupy.here. Stashed with a camper in New York City’s Zuccotti Park, the router offered a local forum where people could share ideas or leave messages for one another.

There are obvious limitations, says Kurtis Heimerl, who builds technology for developing regions at the University of Washington. “So much of the internet is about connecting people to other people,” he says. “These solutions don’t deal with that.” ■



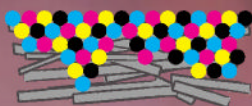
What would you carry?

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Belt up, dummy

AND you thought your job was tough. These are the unsung heroes of car design, awaiting their violent duties at BMW's Research and Innovation Centre in Munich.

They may be slammed into walls or other vehicles, have bones broken, spines compressed or joints ripped apart – but it's all in a day's work.

These crash test dummies' steel skeletons are covered in rubber, vinyl and foam. They come in families, representing men, women, boys and girls of varying ages and builds, and each dummy is fitted with up to 120 sensors to measure the forces of an impact. They wear ID tags which, like patients' charts in a hospital, record their statistics and history.

Before each crash, the dummies' sensors are calibrated and tested (see picture below). After their bone-crushing ordeal, the sensors tell BMW's engineers where it hurts.

Then the dummies have their broken parts replaced before being strapped in again.

Photographer Edgar Martins spent 18 months in BMW's plant and research centre for his latest project, titled *00:00.00*, shooting during breaks to capture the facilities devoid of humans.

Martins, who has previously photographed at the European Space Agency's facilities and old power stations in Portugal, says his aim is "to examine and re-evaluate our relationship with technology and industry and its impact on our social and cultural consciousness". Sam Wong



Photographer

Edgar Martins

edgarmartins.com

Moral dilemma

Attempts to bolster virtuous traits in the young are on the rise. But no one knows whether they actually work, says **Christian B. Miller**

IT IS a common refrain down the ages: the young of today lack the backbone of earlier generations. In the UK, education secretary Nicky Morgan is ploughing £3.5 million into efforts to instil characteristics such as grit, resilience and self-control in state-school pupils, and millions more have been pledged for military cadet units in schools, partly to bolster such traits. Across the Atlantic, the US has long invested in character education.

Putting aside the debate about whether a grit deficit exists, what does science say about character and how it's shaped?

The very existence of character has been hotly disputed by those who argue that how we act is simply a reflection of external circumstances and not internal traits. But there is now strong evidence from psychology that character exists, that people differ



in traits and that character is not immutable but can change and be improved, whatever you think about its heritability. There is evidence that it influences behaviour – from criminal acts to charitable giving – and correlates with longer-term prospects.

We also know that character traits split into at least two groups: performance virtues and moral virtues. Grit, self-control and resilience are all performance virtues. A lot of formal character education focuses on them.

But these traits are found in both the best of saints and the worst of sinners. An assassin might show a lot of grit if he or she spends years tracking down a target. More grit does not necessarily equate to a desirable outcome.

That is why, among other reasons, we must cultivate moral virtues, too. Traits such as

Drones of contention

It is a flight of fancy to think hobby drones can avoid tougher regulation, says **Jeff Hecht**

DOES the thought of a drone over your garden make you fly off the handle? You're not alone.

Attitudes to civilian drones are going through a familiar cycle: first they were welcomed, potentially revolutionising delivery, newsgathering and security. Then prices crashed and a consumer craze took off. Now

they mainly make headlines as a nuisance and threat to aircraft.

Although the misuse of new technology is familiar, it's impossible to anticipate all its forms. Alexander Graham Bell didn't think about telemarketers turning the phone into a nuisance. Email creators didn't imagine spam. And when weather

balloons were first used in 1896, who would have thought that nearly a century later US truck driver Larry Walters would tether a few dozen to his patio chair and fly into controlled airspace?

Drones flown for fun are not all small and harmless. This summer a helicopter in California narrowly missed a 2-metre drone and a 1-kilogram model knocked out a woman in Seattle. Pilots have reported drones disturbingly close, even 3000 metres up. The

"Who'd have thought a man would use balloons and a patio chair to fly into controlled airspace?"

Federal Aviation Administration (FAA) received 137 such reports in July, up from 36 in the same month last year. A few weeks ago drones flocked above Californian wildfires, grounding fire-fighting planes. "I can't believe hobby drones are risking lives to get videos," said Senator Ted Gaines.

As the backlash grows, irate citizens may take matters into their own hands. Also this summer a Kentucky man shot down a drone he claimed was hovering over his property. Last month an Idaho company began selling anti-drone shotgun shells. The fears may be overblown but they are not irrational. Fools don't

honesty, compassion and respect balance the performance virtues and are vital for society to thrive.

To a degree, character education happens informally in classrooms around the world. Character is shaped when a teacher tells a student to clean up a workspace or try again on a project.

What about the effectiveness of dedicated character-education programmes? Here we are largely in the dark – in most cases we do not have enough evidence to say whether they even enhance traits.

Take moral virtues. Only a few character-education programmes have been subjected to sufficient research, and in those cases it was unclear whether the benefits accrued were as a result of the development of moral virtues.

The same is true for performance virtues. In the case of grit, I am not aware of a single published study that assesses the effectiveness of interventions.

So although the increased attention to character education is important, a big question remains: are these programmes actually doing the job? ■

Christian B. Miller is a professor of philosophy and director of the Character Project at Wake Forest University in Winston-Salem, North Carolina

read instructions but they can get drones aloft and out of control. Crooks use them to deliver drugs and guns to prisons.

So California is eyeing new laws and the FAA has updated its 1981 model aircraft operating standards, the only federal guidelines for hobbyists. But real change would require repeal of a 2012 federal law preventing the FAA from regulating hobby fliers.

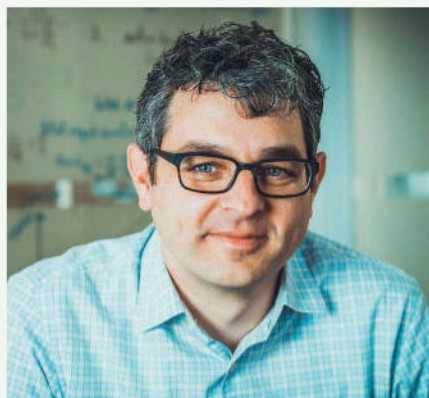
No one wants to spoil the fun but this regulatory vacuum can't continue. As with model rockets, we need sensible rules to ensure public safety. ■

Jeff Hecht is a *New Scientist* consultant

ONE MINUTE INTERVIEW

Save data, save lives

Intensive care units gather huge amounts of patient data, but much of it gets thrown away. Give it to me, says **Thomas Heldt**



PROFILE

Thomas Heldt is an assistant professor of electrical and biomedical engineering at the Massachusetts Institute of Technology, where he leads the Integrative Neuromonitoring and Critical Care Informatics Group

You're trying to start a data revolution in hospitals. Why?

I'm interested in clinical environments such as intensive care units, operating rooms and emergency rooms. These are places where huge amounts of data is gathered from patients at great expense. What surprised me when I entered this field is that this data is collected and displayed on a monitor, but after a holding period of between 48 and maybe 96 hours, it just gets deleted. It never becomes part of the medical record. I see that as a wasted opportunity.

What happens to the data while it is collected and temporarily stored?

Clinical staff might look at the monitors to check the data as it is collected. They might scroll back to see what happened 8, 12 or 24 hours earlier. Occasionally they might want that kind of information if something really bad or unexpected happens, but even then they would probably rely on the medical notes rather than the real-time physiological data that came off the monitors.

So usually not much is done with this data after it has been collected and displayed.

Which types of patients are you targeting?

People with brain injuries and very premature babies are two examples. Most babies go on to be just fine but some develop severe brain injuries or serious complications that affect their gut or lungs. A day or so before it happens, you might have no idea there's anything wrong. It's only when you see a massive bleed in the head on a scan, or when you send them to the imaging department and you discover that their gut has become necrotic. The aim of my approach is not only to analyse the data coming off the monitors but also to use it to predict and prevent these kinds of injuries and complications.

How do you make sense of the data?

It is coming out of a system that has been studied for over 200 years: our physiology. Physiologists are very good at rooting their understanding in the language of basic mathematics or in engineering principles such as conservation of momentum, flow or energy. Using these kinds of principles one can quantify in a mathematical sense what is going on in patients and build models to describe it. Such models will enable us to warn doctors, "OK, so this is about to happen". Not only that, we will be able to say: "This is about to happen because of X, Y and Z, and here's how you could intervene."

Are we on the cusp of a transformation in how hospitals deal with this data?

I think we are. For example, Boston Children's Hospital now captures all of the data from every bedside monitor routinely. We recently had the luxury of rolling back up to 48 hours into the intensive care data, and we did see trends. We saw how patients could deteriorate very, very slowly – something that you probably wouldn't be able to pick up over the course of a single nursing shift. When we presented this to clinicians it was a revelation to them.

Interview by Jessica Griggs

Our superhuman future is just a few edits away

A breakthrough in gene technology is opening the door to a brave new world. **George Church** is poised to step through

There has been a lot of excitement lately over the new gene-editing technology, CRISPR. How does it work?

Gene editing is snipping out a targeted DNA sequence and replacing it with another. It used to be time-consuming and imprecise, but now you can edit any living genome, using your computer to target a stretch of DNA. Guides made of bespoke RNA lead the CRISPR molecular machinery to the target, where an enzyme makes a cut. This either destroys the function of the DNA in that location or allows you to change its functioning by manipulating how the cells repair the cut, for example by inserting a genetic sequence of your choice.

What will we be able to do with CRISPR?

It could enable gene therapies that would allow physicians to fix genetic diseases, including some types of blindness, the blood disorder beta thalassemia and the neurodegenerative disorder Tay-Sachs disease. It could also mean new approaches to treating cancers and viral infections, including HIV.

Other techniques could allow helpful DNA to spread through wild animal populations – which may allow us to eliminate infectious diseases like malaria.

Earlier this year, there was controversy when a team in China attempted to use CRISPR to edit the genes of non-viable human embryos. For some people this still crossed an ethical line. What are your thoughts?

In the early days of any field, if you mess up enough, you don't just mess up your lab, you mess up all the labs. I don't think this brouhaha will kill gene editing – they didn't hurt any patients. But they were incautious.

From a technical point of view, there are several widely known techniques that have been proven to improve the specificity and efficacy of CRISPR gene editing, some of which were developed in my lab. The Chinese group must have known that their work was going to get a lot of attention, so it was disappointing that they chose not to use these techniques. They may have felt that if they waited to do it the right way, another lab would have scooped them. In practice these other labs, mine included, are not doing CRISPR research with human embryos, so I don't know what they were worried about.

Mediocre science is not the same as evil science – after all, the experiments they did are legal in most countries.

So you're not worried about the ethical issues that have been raised?

For me, the safety issues are the ethical issues, and the safety issues are not fundamentally different from those of any new therapeutic. Gene-editing techniques are being tested in animals extensively, in primates as well as rodents, and will eventually move into people.

I'm a professional worrier. But the form that my worry takes is action. As soon as somebody expresses something to me that they think is wrong with the world or with research, I say "let's work on this". We can innovate on safety measures.

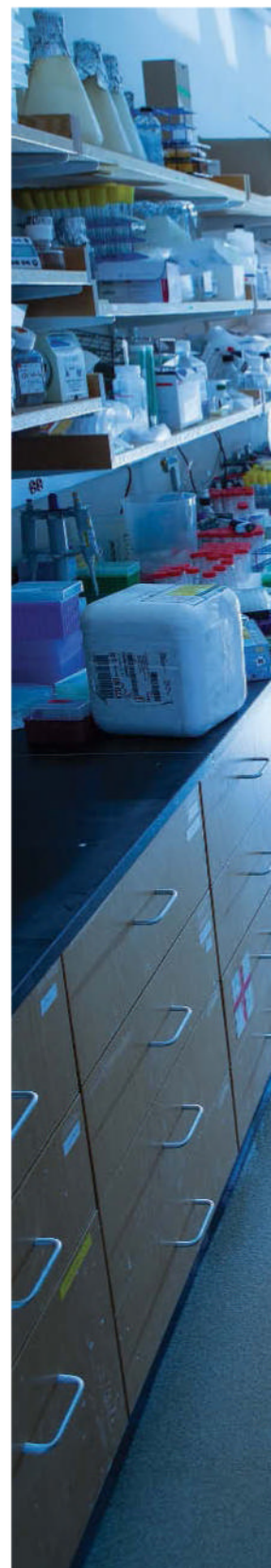
Some people are against any tinkering with the gene pool – summoning the ever-present spectre of designer babies.

We humans already tinker with the gene pool with inherited diseases such as Tay-Sachs: genetic counselling before or after conception

PROFILE

George Church is a professor of genetics at Harvard Medical School. He is also the director of the Center for Causal Consequences of Variation, a National Institutes of Health centre of excellence in genomic science, and director of PersonalGenomes.org.

My stance on safety and ethics is that they are indivisible





can help parents to decide on the health of their future children.

We tinker with the gene pool every time we fly at high altitude, which increases random mutations in developing sperm and egg cells. These things are allowed. If you don't like the concept of tinkering with the gene pool, then ban it across the board. Don't be exceptional about CRISPR.

Then there's the issue of what we value. Do we value long life, intelligence, athleticism, beauty? We are already making our children more educated than their ancestors, and typically we do that without the permission of the children. People pay for products that improve beauty and athleticism. If you don't think those are good values, then ban tinkering with them. But be fair. Don't ban a particular form of it – unless it's unsafe.

Should unborn children have the right not to have their parents genetically dictate who they become, or is it the parents' choice?
Parents owe it to their children to provide them with a good start. Education, chores,

“People worry that gene editing is irreversible, but that notion is a straw man”

nutrition, dress code, faith and curfews are often dictated by parents for the good of the child. And parents already use genetic counselling to guide pre-conception and prenatal choices, to dictate that the child will not be burdened by serious genetic disease. Once those children grow up, they can choose different dictates for their own children as new information about genetics and child rearing becomes available.

There are also concerns that genetic modification affecting sperm and eggs will produce changes that are irreversible and that can be passed down through the generations.
The irreversibility argument strikes me as a straw man because, clearly, gene editing is not irreversible on a population-wide level.

If the population is changing because individuals are making decisions, it can change back if governments or individuals make alternative decisions. In fact, it can change back more readily because the technology is improving all the time and the costs are reducing. Now, it could be that people won't want to reverse the changes, but that's telling you that the change is valuable in some way.

JASON GROW PHOTOGRAPHY

If humanity doesn't take the opportunity to advance genetic engineering in people, are we doing ourselves a disservice?

Absolutely. This question should come up more frequently. With seven billion people and growing, sitting still is not really a great option. For example, we could wipe out malaria using a gene drive – a technique that would allow a malaria-resistance gene to spread through a population of mosquitoes extremely rapidly.

That could be risky.

Some of us may say that gene drives are too risky in general because of unknown unknowns – like perhaps causing the extinction of a mosquito species. But if you did, it's unlikely that that is going to kill any other animal. And every year that we hesitate, 600,000 people die of malaria unnecessarily and another couple of million get sick and miss days at work. That's a pretty big price to pay.

You're also interested in what's called genetic augmentation. Isn't using gene therapy in that way, whether for physical or mental enhancement, controversial too?

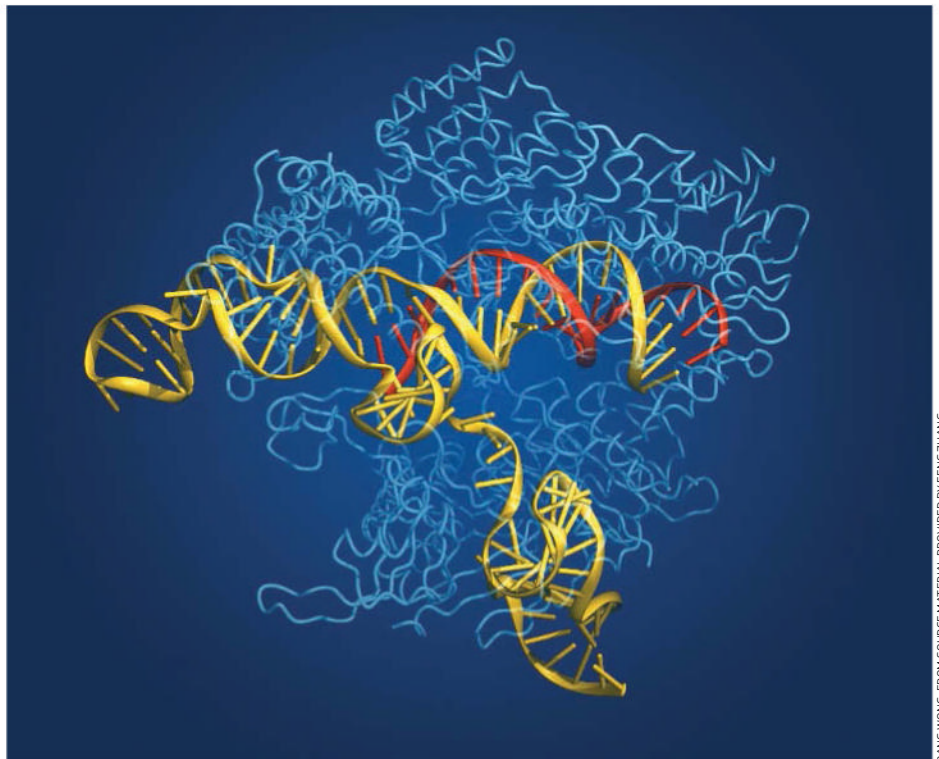
It's less controversial because it would be in consenting adults. If a majority agrees that adults can be augmented – using a new drug, device, or gene therapy – then as long as it passes the usual safety and efficacy rules of the US Food and Drug Administration (FDA), in my view it's not controversial enough to prevent rapid adoption.

You've famously come up with a list of 10 particularly protective but rare gene variants that we might all benefit from. Yes. For example, PCSK9 protects you from cardiovascular disease, and it's "superhuman" in the sense that people who have it are well

"Einstein said our technology exceeds our humanity. I don't buy that"

beyond the average human in terms of low cardiovascular risk. Three others on the list – *MSTN*, *LRP*, *APOE* – will probably lead to therapies to prevent muscle degeneration, osteoporosis and dementia.

What about genes unrelated to disease? If we go in for editing such genes, what kind of society will we end up with?
It comes down to what societies value, and then what individuals want.



Enzymes (pale blue) cut target DNA (red), guided by RNA (yellow) – it's CRISPR in action

I don't think everyone will want the same thing: we won't all suddenly become exactly 5 feet 10 inches tall, with blonde hair and blue eyes. I think augmentation will actually increase diversity.

Some of it will be driven by need or ambition. People who want to go to space may want super-strong bones to protect them from osteoporosis in low gravity, while people who go to live at the bottom of the ocean will want a different set of modifications. And people who want to be super bankers are probably going to want a different set than the people who want to be super athletes. There isn't a best kind of human, just like there isn't a best kind of car.

If you're going to worry – which I do all the time – I would worry about adult augmentation, because it will spread fast. If I were to augment a child, an embryo, it will take 20 years before they have any significant impact on society.

But if I come up with an augmentation that improves adult intelligence, news of that will go through the internet at light speed and a lot of people will try it. And then if it's successful in the first million people who try it, then there could be a billion people who try it.

In 2012 you published a book entitled *Regenesi*s, and you have talked about your lab as a centre for new technology aiming to rebuild creation to suit humans. Set that alongside your appearance and your name, and is it any wonder people accuse you of playing God?

It's certainly not my intention. But we're engineers – making our world suit us is what we do. It's what humans do. The term "playing God" is mainly used to imply that you are doing something beyond your means.

I agree that we need to be cautious and I actually feel that humanity generally does move forward in steps. It can seem very fast and can, ultimately, happen in gigantic leaps – like landing on the moon and eliminating smallpox – but these things are done cautiously.

Yet technology is advancing at a blistering pace. Einstein said our technology exceeds our humanity. I don't buy that. I think that even when technology is going very fast, we have tried-and-tested traditional ways of reining it in. We don't need special bans or a moratorium – we have the Environmental Protection Agency, we have the FDA. We need to think big, but also think carefully. ■

Interview by Jessica Griggs



MICHAŁ PRZEDŁACKI

In the line of fire

Palmyra, Nimrud, the Bamiyan Buddhas - the list of antiquities felled in recent years goes on. But at one site in Afghanistan, insurgents aren't the greatest threat, finds **Andrew Lawler**



JAROSŁAB PONCARI

Thousands of ancient artefacts and stupas have been recovered at Mes Aynak

THE rocket attack began around 10 pm, after the western sky behind the rugged mountains of Afghanistan's Logar province had faded to black. In the remote camp, a 90-minute drive south-east of Kabul, explosions and gunfire startled archaeologists out of their beds.

The Taliban attack, in May 2013, was an attempt to overrun the heavily guarded compound that is home to one of Central Asia's largest Buddhist ruins, an international team of archaeologists – and a group of Chinese miners. It failed, but resistance came at a cost. "Five soldiers died defending us," recalls Roberta Marziani, an Italian researcher.

Excavating ancient sites is typically dirty and backbreaking work. But at Mes Aynak, 2500 metres up in the Hindu Kush mountains, archaeologists must also cope with the threat of violence and stray landmines planted long ago by Soviet forces. The site was once a key stop on the ancient Silk Road connecting Europe, India and China (see map, page 32). It was occupied for at least a millennium by monks, artisans, traders and soldiers. They left behind a dazzling array of stupas, walled monasteries, workshops and homes filled ➤

Endangered archaeology

The early mine and temples of Mes Aynak – set to be destroyed to make way for a Chinese copper mine – were at a crossroads of the ancient **trade routes** known as the Silk Road



with thousands of Buddhist statues, paintings, manuscripts, coins and gem-encrusted jewellery.

These treasures (see pictures, page 34) are in an area where the Taliban and the Afghan government vie for control, and repeated attacks have succeeded in all but shutting down excavations. Marziani and most Western experts left in March 2014. But the real threat to the site doesn't come from the Taliban, who infamously destroyed the giant Bamiyan Buddhas to the north-west of Kabul in 2001. Instead, bulldozers and dynamite operated by a Chinese state-owned mining company are to turn the area into a vast open-pit mine.

The attraction is one of the planet's richest copper deposits – right beneath the ancient ruins. It is the reason this region once thrived: "Mes Aynak" means "little copper well" in Dari. Afghan, US and World Bank officials hope the mine will pump much needed revenue into Kabul's empty coffers by producing up to 343,000 tonnes of metal each year.

Afghanistan's per capita income is less than \$700 a year, making it one of the world's poorest nations, but the CIA estimates that well over \$1 trillion in minerals are waiting to be extracted within its borders. Mes Aynak is the centrepiece of that push. It could contain more than 5.5 million tonnes of copper and provide hundreds of millions of dollars annually along with more than 4000 jobs. So in 2008, the Afghan government leased the mining rights to the Metallurgical Corporation of China (MCC) for 30 years, in a deal worth \$3.5 billion.

Wahidullah Shahrani, Afghanistan's minister of mines until earlier this year, insists that conservation work can coexist with mine

preparations and says no mining will take place before the archaeological work is done. But the majority of the ancient site's 50 hectares – roughly the size of Pompeii – sits directly on top of the copper deposits. The vast open-pit mine would inevitably destroy the heady mix of Hellenistic, Persian and Indian architecture at the surface – not to mention the older layers that are thought to reach back to the Bronze Age. No site on Earth places cultural heritage more at odds with economic development.

It's no accident that generations of monks lived in sumptuous monasteries above this vein of ore in a hardscrabble region of bleak and barren hills. Nor will the Chinese be the first to reap its riches. Beneath the stupas is a maze of shafts and tunnels. Radiocarbon dating of organic material found at the site suggests it was mined for at least a 1000 years, from the 2nd century BC until the arrival of Arab armies during the 8th century AD.

Zemaryalai Tarzi, former head of the Archaeology Institute of Kabul, was among the first archaeologists to explore the site in 1973, before the invasion by the Soviet Union shut down research. "Everywhere, traces of metallurgy are visible on the surface," he says. The ancient miners left behind workshops, blast furnaces and 10-metre-high mounds of blue-black slag. Such huge quantities of slag mean the copper ore was both mined and smelted on-site. Underground, Tarzi found a bewildering network of galleries and tunnels, some so small that they point to frequent use of child labour.

Silk crossroads

To those few who have visited Mes Aynak, it offers a unique glimpse into a sophisticated early mining economy. "You should see the mine shafts we have here," marvels Agnieszka Dolatowska, a Polish archaeologist still working at the site. Some reach 40 metres in depth. "Nowhere else in the world can you find so many remains of ancient mining and metallurgy," Tarzi calls it "one of the most intriguing mining sites in Central Asia, if not the world".

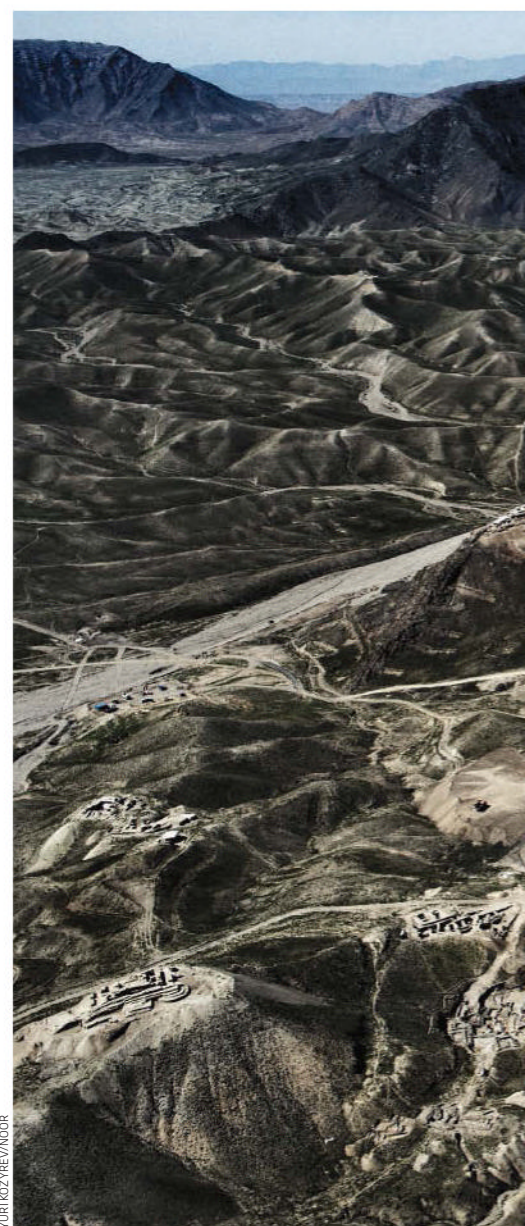
The finds suggest Mes Aynak was probably an industrial site first and a religious one second. Copper ore was a vital part of the early international economy, particularly as copper coins came into widespread use and Europe and Asia were closely linked by the Silk Road for the first time in history. The residents of Mes Aynak were part of the Kushan Empire that united much of India and Central Asia in the 1st century AD and traded for Chinese dishes, Egyptian glassware and Indian ivories.

Tarzi and other archaeologists now suspect that the mine was a key revenue source for the Kushans and the empires that followed. For several centuries, the Mes Aynak's merchants

used its proceeds to fund Buddhist monasteries, construct stupas and pay artisans to produce vast quantities of religious art. Paintings have been found showing what seem to be well-heeled donors in elegant clothes and make-up sitting at the foot of the Buddha.

Excavators have uncovered an astonishing mass of material dating from this heyday. It suggests this was a highly cosmopolitan settlement open to far more than devout Buddhists. A Zoroastrian temple and a statue of Ardokhsho, an Iranian goddess also associated with the Indian deity Lakshmi, testify to a religious mixing and tolerance in the region. Digs at Bamiyan, in contrast, have recovered scant non-Buddhist material.

Chinese miners (blue roofs) prepare to turn the ancient ruins into an open-pit mine



"The Silk Road was significant because of the movement of religions, ideas, technologies and languages that it enabled," says Tim Williams of the University College London, in the UK. "That is how it changed the world. Mes Aynak reflects that complexity."

Dolatowska says there is evidence of strong influences from India and remnants of the Greco-Bactrian culture left after Alexander the Great's foray into Afghanistan in the 4th century BC. And there are signs that the Sasanian Empire, based in Persia and firmly Zoroastrian in its beliefs, reached deeper into Afghanistan than once thought, controlling Mes Aynak on and off after the 4th century AD. Then, sometime in the 8th century the site was abandoned.

Soviet geologists rediscovered it in the 1960s. In the 1990s, with the Taliban in charge, Al-Qaida used the area as a training camp ➤

"Generations of monks lived in sumptuous monasteries above a rich vein of copper"





"Fortunately, a precipitous drop in copper prices have delayed mining"

A delicate, 5-centimetre-tall figure of Bodhisattva once decorated a stupa (below)



MICHAŁ PRZEDŁACKI

and way station for some of the 9/11 hijackers, unaware of the heathen idols buried just below. In the 2000s, locals noticed valuable artefacts and began looting. Then, in 2008, the deal was struck with the Beijing-based MCC to once more make Mes Aynak a centre of power and wealth for the struggling nation.

Not long after the deal was signed, archaeologists found evidence of extensive Buddhist ruins at the site of the proposed pit. Omar Sultan at the Ministry of Information and Culture and Philippe Marquis, who headed the French archaeological mission in Kabul, sounded the alarm. The government reluctantly agreed to allow three years of archaeological excavations before demolition began. The World Bank chipped in \$8 million to fund the archaeology project, with support from UNESCO, the French mission and the US government. Work began in earnest in 2010.

But today work is slow. Mes Aynak is remote, unwelcoming and downright

dangerous. Two concentric rings of fence surround a 4000-hectare area, with the ancient ruins at its centre. Dozens of checkpoints and 1500 guards make this one of Afghanistan's most fortified compounds outside Kabul. Inside is a camp for Chinese workers (see picture, page 33), located on top of a monastery called Gol Hamid. The Chinese have fled the site several times in the wake of Taliban attacks over the years. At least one of their workers was killed by improvised explosive devices on the Kabul road.

A key question for scholars of the ancient world is when and where miners first began to extract copper. Jonathan Kenoyer, a University of Wisconsin archaeologist who has visited Mes Aynak, suspects they were at work there as early as 2000 BC, when Bronze Age civilisation flourished along the Indus river valley to the south. This possibility, he says, makes the site extremely significant for understanding the role of metals and trade in



LEFT: JAROSŁAW PONCZAK, RIGHT: YURI KOZYREV/NOOR



Thousands of ornate statues and hoards of gold and gemstones are a testament to the past riches of Mes Aynak



early urban societies. Marek Lemiesz, who led the international effort until this summer, has said that under normal circumstances it would take at least 20 years to excavate such a site. To get at the older layers archaeologists must first carefully excavate and catalogue materials found above them, a time-consuming and expensive process made nearly impossible by the current security situation. There is no time to extend our knowledge of that period, says Dolatowska.

Fortunately for archaeologists, a precipitous drop in copper prices, contract disputes and delays in building the railroads, power plants and smelters necessary to extract and ship the metal out, have all pushed back the date for construction of the open-pit mine. "There is no way that mining can commence at that location in anything less than three years, probably more," adds Cheryl Benard, head of the Washington-based Alliance for the Restoration of Cultural Heritage.

Dig in disarray

It's small comfort for the archaeologists. According to interviews with foreign academics and reports from the Ministry of Mines and Petroleum, the excavation is in serious disarray. Only half a dozen Western archaeologists remain; the ministry says at least 10 are required to maintain minimum excavation standards.

In June 2014, insurgents executed eight workers who were clearing landmines in the area. Security concerns and a strike by local workers who hadn't been paid for six months led the government to shut the entire site for most of that summer and into the autumn. It has recently refused to extend Lemiesz's contract as lead international archaeologist, according to Dolatowski, and he has yet to be replaced. Lemiesz couldn't be reached for comment, but in his 2014 reports he complained about rocket attacks, roadside

bombs inside the security zone, poor management and clashes with Afghan colleagues over digging methods.

Sultan, who now liaises between the Ministry of Mines and Petroleum and the Ministry of Information and Culture, declined to discuss Lemiesz's employment. He insists that the site is now safe and that Western archaeologists will soon return. "I just spent two nights there," he says. "There is no security problem." He says work continues with the help of 182 labourers overseen by Tajik and Afghan excavators and a skeleton crew of Westerners.

Others say that part of the problem is a turf war between the two ministries. "To put it simply, on the Ministry of Mines side there is too much money and poor management – not to say mismanagement," says Marquis. And at the Ministry of Information and Culture, which is responsible for the archaeology effort, there is too little money and experience in dealing with a budget, he adds.

"You have to understand that in Afghanistan this is quite normal," says Marziani. "You don't always get paid on time."

In the meantime, the five years of work has amassed an astonishing amount of material, but little has been analysed. More than 1000 statues have been recovered, from massive Buddhas to a small, delicate terra cotta figure of a woman breastfeeding a child. Recently, a fragile manuscript emerged, that some reports claim mentions Alexander the Great.

The sheer scale of the site and huge

numbers of artefacts would pose a challenge for even the most well-equipped, trained and funded archaeological team. "They have been digging Pompeii for a century, and there is still more to be found there," says Marziani.

Smuggled coins

To make matters worse, archaeologists worry about the fate of the material that has already been dug up. Many of the finds have been sent to the already crowded National Museum in Kabul. Sultan says another storage facility will soon be ready. But the World Bank's Michael Stanley notes that any large cache of Buddhist material could prove a tempting target for the Taliban.

Archaeologists are also concerned that the mass of artefacts on site will prove irresistible to looters. Statues such as those found at Mes Aynak can go for tens of thousands of dollars on the international art market. Afghan officials have already accused Tajik specialists of damaging artefacts they tried to smuggle out of the security zone, though it isn't clear if anyone was prosecuted. Marquis says he has encountered vendors selling Sasanian coins clearly identified as originating at Mes Aynak. "If the people on site aren't paid," he adds, "this is going to be more and more frequent."

Whether archaeologists can take advantage of the grace period offered by the drop in copper prices remains an open question. As the US withdraws from the country, donors tire and the Taliban continues its attacks, ancient sites like Mes Aynak are increasingly in jeopardy. "It's a big sacrifice to be there," says Marziani, who worked at the site for two years. "You go to Kabul maybe once a month for a meal so as not to go crazy. It was a good experience, but a hard lifestyle." ■

Andrew Lawler is based in North Carolina. He is author of *Why Did the Chicken Cross the World? The epic saga of the bird that powers civilization*

"Any large cache of Buddhist material could be a tempting target for the Taliban"



IN JUNE, a new voice backed up what many scientists have been saying for a while – that climate change is caused by human activity and we have a moral responsibility to tackle it. In a historic edict, Pope Francis warned that failing to act would have “grave consequences”, the brunt of which would fall on the world’s poorest people. His words came as a stark reminder that global climate change is among the most pressing moral dilemmas of the 21st century.

It joins a long list. He could have added spiralling inequality, persistent poverty, death from preventable diseases and nuclear proliferation to the ethical challenges that define our times. Some are newer than others, but all could plausibly be fixed. The fact we’re struggling with all of them raises a troubling question: does our moral compass equip us to deal with the threats we face today?

For many of the pope’s billion-strong flock and other believers, moral judgement is an operation of the mind beyond scientific explanation. In recent years, however, psychologists and neuroscientists have gone a long way towards understanding the machinery underlying our moral thinking and behaviour. In the process they are getting to grips with what really drives how we decide what is right or wrong. Their insights are not only revealing the limitations of our moral minds, but also suggesting how we might manipulate them – by employing psychological tricks, or even pills and brain zaps.

Human moral psychology evolved over tens of thousands of years as we became an ever more cooperative, social species. Early humans living in small bands were forced to hunt and forage collectively or starve.

That requires cooperation, which fuelled the evolution of cognitive facilities underlying collective action – the ability to share goals, responsibilities and rewards.

“Morality is a device for solving the social challenges of everyday life, where the basic problem is to get otherwise selfish individuals to work together as a group and enjoy the benefits of cooperation,” says Joshua Greene, a neuroscientist at Harvard University.

So how do we make these everyday decisions? One key insight came from New York University psychologist Jonathan Haidt, who revealed that moral judgements are frequently driven not by rational, reflective thought but by intuitions and gut feelings.

In one study he quizzed people about the morality of various acts, from cleaning a toilet with the US flag to having sex with a chicken bought from the supermarket. Participants often said these acts were immoral and clung to these judgements even when they couldn’t provide good reasons for doing so. Frequently, they’d throw their hands up and say, “It’s just wrong!” – a phenomenon Haidt calls “moral dumbfounding”.

This moral intuition is often fuelled by emotional reactions. Most people are repulsed by the thought of a human engaging in coitus with a deceased chicken, and that alone is enough to condemn the act. When reasoning comes into play, it is frequently to rationalise these intuitive decisions after the event.

Yet we are not slaves to emotion. “We have gut reactions that guide our judgements and behaviour,” says Greene, “but we can also stop and think, and reason explicitly about situations to try to make better decisions.”

Greene has shown how this plays out in the brain by getting people to mull over dilemmas

as they lie in an fMRI machine. A famous example considers whether it is morally permissible to push one person off a bridge on to railway tracks to stop a runaway train from hitting five people stuck just ahead, killing the person in the process. Most people feel a strong gut reaction to say no, which shows up as increased activity in brain regions

“WE TEND TO MAKE QUICK-FIRE MORAL JUDGEMENTS BASED ON EMOTION AND GUT REACTION”

that process social emotions. The upshot is that aversion to up-close-and-personal violence trumps the greater good.

But if you instead ask whether it’s OK to flick a switch so that the runaway train is diverted from the track with the five people on it and towards another where it will hit and kill just one person, most people say yes. The moral maths is the same, but hitting a switch just doesn’t feel as bad. Greene’s studies indicate that responses to these kinds of dilemmas are dominated by colder, calculating processes grounded in the “rational” dorsolateral prefrontal cortex.

Greene likens our moral psychology to a digital camera. Intuitive moral sentiments are akin to the automatic settings, he says, while rational deliberation is analogous to manual mode, where you adjust everything by hand. “The automatic settings are good for the situations for which they’ve been programmed, making them efficient but not very flexible,” says Greene. “Manual mode is flexible but not so efficient, as it takes time to punch in the settings.”

In the same way that many of us rely on ➤

Can we hack our outdated moral psychology to save the world? Dan Jones investigates

MORALITY 2.0



Would linking flying with harming our kids make us more aware of climate change?

auto mode on our cameras because it is easier, we tend to make quick-fire moral judgements based on gut reactions. So here's the question: is auto-mode moral decision-making, which evolved to navigate small-scale social worlds, suited to handling issues that impact millions of distant strangers and future generations?

Greene thinks not. "These are very good at solving the problems of everyday life, but not global moral problems like environmental destruction or poverty in faraway places."

Take empathic concern, one of the key features of auto-mode morality. Roughly speaking, this is feeling the pain of others. It functions like a spotlight, throwing into stark relief the plight of whoever falls

"YOU MIGHT THINK EMPATHY IS AN UNALLOYED FORCE FOR GOOD. YOU WOULD BE WRONG"

under its beam, and moving us to action. So you might think empathic concern is an unalloyed force for good.

You would be wrong, says Paul Bloom, a psychologist at Yale University. "Empathy, being a spotlight, is very narrow," he says. It illuminates the suffering of a single person rather than the fate of millions, and it is more concerned with the here and now than the future. "It's because of empathy that we care more about, say, the plight of a little girl trapped in a well than we do about potentially billions of people suffering or dying from climate change," says Bloom. The visceral reactions towards recent photographs of a dead Syrian boy washed up on a Turkish beach provide another case in point.

Empathy's shortcomings are compounded

by the fact that we end up pointing its beam on causes that happen to come into our field of view – typically the most newsworthy moral issues, rather than those where we can do the most good. The response to the 2004 Boxing Day tsunami, in which some charities received more donations than they could spend, is one example.

All this sounds a bit disheartening, but there is hope. "We can use manual mode to train automatic mode," says Fiery Cushman, who runs a moral psychology lab at Harvard University. "In the past 10 years, we've learned that there's an enormous role for learning in shaping our moral intuitions."

In a study out last year, for example, Cushman asked people how they would feel about performing a mercy killing on a terminally ill man by various methods, including giving him a poison pill, suffocating him and shooting him in the face. You might expect opposition to each method would be predicted solely by the amount of suffering it causes. But Cushman found that it was better predicted by participants' aversion to performing the action (*Emotion*, vol 14, p 573).

So it looks like we base our instinctive moral judgements not only on our emotional reaction to suffering, but also on how the physical acts that cause it make us feel. And here's where we might be able to change ourselves. We learn to assign moral value to actions through the brain's dopamine system and the basal ganglia, and Cushman suggests we might manipulate this process to shape our instinctive moral reactions.

One approach is to deliberately seek out particular experiences, he says. Imagine an aspiring vegetarian who is concerned about animal welfare. If bacon sandwiches are

proving too much of a temptation, they might watch videos documenting the mistreatment of animals. "This could change their automatic attitudes, so when they see meat in front of them they find it disgusting rather than appetising," says Cushman. The same tactics might help people forge an aversion to actions that increase their carbon footprint, say, or add to the plight of the world's poorest people.

New age of reason

But the choices made by a select few are hardly going to be sufficient. When it comes to creating the large-scale moral change required to solve the planet's greatest problems, Kwame Anthony Appiah, a philosopher at New York University, argues that "the question isn't 'What should I do?', but 'What should we do?'". And although manual-mode thinking can help us set our sights on the causes "we" should pursue, reshaping moral thinking en masse takes more than deliberation and reasoning.

Appiah has studied the history of moral revolutions such as British abolitionism – the 19th-century movement to end the transatlantic slave trade. "The rational, moral and legal arguments for ending the slave trade were well known long before abolition," says Appiah. What tipped the argument over into becoming a movement was that broad swathes of society came to feel collectively ashamed of being engaged in the trade. That shift was driven by activist groups raising awareness of the dreadful human cost and making the anti-slavery cause part of British national identity.

In Birmingham, for example, local politicians and thousands of citizens signed anti-slavery petitions, to be delivered to the British government. "They wanted to be part

"IT MIGHT ACTUALLY BE POSSIBLE TO ALTER MORAL THINKING WITH DRUGS AND BRAIN STIMULATION"

of a city that had done something about this trade," says Appiah. "This civic pride was a big part of the abolitionist movement."

Appiah suggests campaigns that speak to our sense of collective identity – as members of a city, nation, religion or social movement – are likely to be most effective. So why not scale up and play on our shared identity as humans to tackle problems that affect us all? "The problem with the notion of humanity is that there's no outside group to compare against," says Appiah. "It would be a more useful notion if there were some aliens around."

Still, shame at immoral actions and pride in tackling moral problems could yet prove effective. Jennifer Jacquet, an environmental scientist from New York University, argues that we may need to recruit the power of shame to modify moral behaviour on social issues like climate change. "Aimed cautiously and well", shaming can be deployed for the greater good, she thinks.

Take BankTrack, a global network of NGOs that exposes banks involved with projects that threaten the environment and human rights. BankTrack has looked at banks lending to the coal industry, a major source of global carbon dioxide emissions, and compiled a list of the top "climate killers".

Its manifesto is simple: "By naming and shaming these banks, we hope to set the stage for a race to the top, where banks compete with each other to clean up their portfolios and stop financing investments which are pushing our climate over the brink."

However, harnessing the power of rational

reflection, collective identity and shame may not be the only options for would-be moral revolutionaries. In their book *Unfit for the Future*, philosophers Ingmar Persson of the University of Gothenburg in Sweden and Julian Savulescu of the University of Oxford argue that our moral brains are so compromised that the only way we can avoid catastrophe is to enhance them through biomedical means.

In the past few years, researchers have shown it might actually be possible to alter moral thinking with drugs and brain stimulation. Molly Crockett of the University of Oxford has found that citalopram, a selective serotonin reuptake inhibitor used to treat depression, makes people more sensitive to the possibility of inflicting harm on others. Earlier this year, for instance, Crockett and colleagues found that participants who had taken citalopram were willing to pay twice as much money as controls to prevent a stranger from receiving an electric shock (*Current Biology*, vol 25, p 1852).

Biomedical enhancement may even work on complex social attitudes. Roberta Sellaro at the University of Leiden in the Netherlands has shown that delivering low-current electrical signals through the scalp to stimulate the medial prefrontal cortex, a brain area implicated in regulating social emotions, can reduce stereotyped attitudes towards members of different social groups.

Barclays ended financing of mountaintop removal mining in 2015 after protests

Don't expect to see morality pills on pharmacy shelves any time soon, though. These studies are far from conclusive and the effects demonstrated are subtle. Even so, the fact that such behavioural modification is possible raises the prospect that someone might use it.

Of course that raises moral questions in itself – who to treat, how, and at what age? But Persson and Savulescu argue that if the techniques can be shown to change our moral behaviour for the better (who or what defines "better" is another question), then there are no good ethical reasons not to use them. Take the issue of consent, which children could not provide. "The same is true of all upbringing and education, including moral instruction," says Persson.

Moral robots

But wouldn't biomedical moral enhancement undermine responsibility by turning us into moral robots? Persson and Savulescu argue that biomedical treatment poses no more threat to free will and moral responsibility than educational practices that push us towards the same behaviour.

Yet even if moral hacking with drugs and brain zaps could be deemed ethically sound, putting it into practice is another matter. "It's not as if there's a moral circuit in the brain that you simply want to ramp up," says Greene. "Moral decision-making draws on a number of major brain circuits, so you're not going to be able to enhance people's morality in a pinpointed way."

And assuming you could get people to make the "right" choices, how would you deliver artificial moral enhancement across entire populations? Would we add drugs to the water supply? Would we fortify kids' cereal with moral enhancers?

Even if we could overcome these obstacles, Bloom insists that artificial enhancement is not the way to go. "I think people approach it the wrong way, and work under the illusion that we'd be better people if we messed with our emotions in one way or another."

Bloom argues that when it comes to tackling moral problems such as climate change, which we have no reliable instinctive way of dealing with, the best way forward is to try to spend more time in manual mode.

"Moral issues are complicated and hard, and they involve serious trade-offs and deliberation. It would be better if people thought more about them." ■



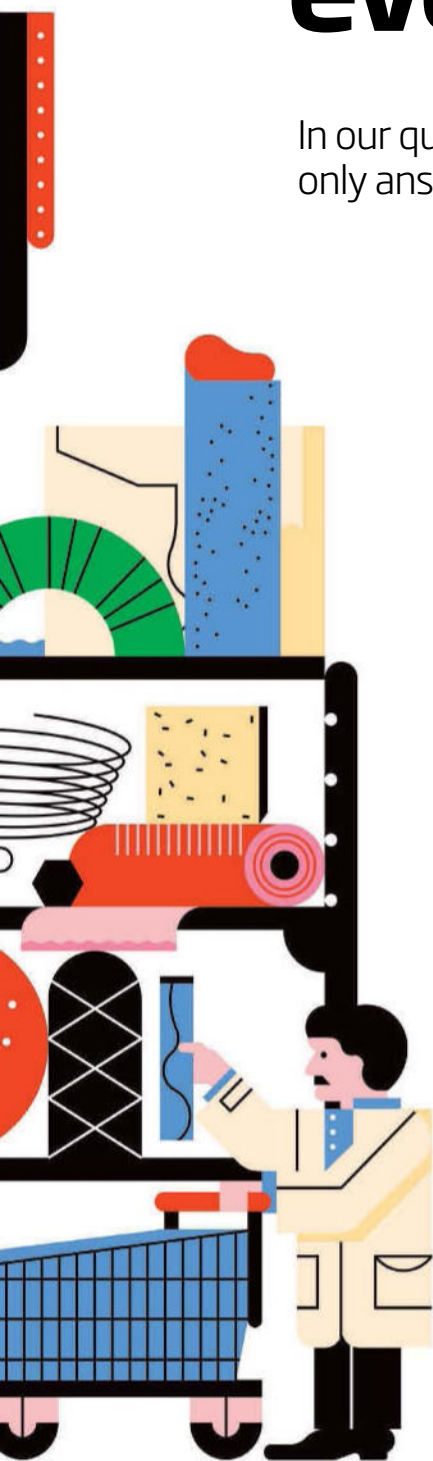
DANIEL LEAL OLIVAS/IMAGES

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Welcome to the everything factory

In our quest to discover superlative materials, maybe the only answer is to make them all, says Leigh Phillips



SOME wonder technologies, such as the personal jetpack, were never really serious propositions. But researchers in the 1980s did confidently promise we would all soon be travelling in superfast levitating trains. The choke point was the need for a material that conducts electricity with zero resistance at room temperature. Without such a superconductor, the magnets that power the few maglev trains that do exist are incredibly power hungry.

It's the same story with a host of other technologies: our inability to make the right materials is holding things up. Cheap, efficient solar panels require substances that can convert huge amounts of sunlight into electricity, rather than the measly quantities they manage now. Low-energy lightbulbs work well enough, but rely on rare and expensive elements. And don't even mention batteries – the quest for better ones has been consuming research dollars worldwide for an age (*New Scientist*, 25 July, p 21).

It's all down to the bothersome way we hunt for materials. When we realise we need one for a particular job, we either scour nature or try combining elements in novel ways to find something that fits. There's no guarantee of success, and failures eat up time. We can't make every possible material at once.

But what if we were to make them inside a computer, all the materials we can imagine – and all the ones we can't? That's just what is beginning to happen, with a virtual materials hypermarket that is starting to build up its stock. Who knows, perhaps even the material for that personal jetpack might soon be in store.

From our ancestors' earliest use of stone tools to the invention of porcelain in Han

Dynasty China and our own use of tungsten in light bulb filaments, the history of materials discovery has been one of serendipity and intuition. It was only in the second half of the 20th century, as we began to fully get to grips with quantum mechanics, that we gleaned a more fundamental understanding of why materials act as they do.

The central insight was that the properties of any material – its hardness, electrical conductivity, reflectivity, resistance to corrosion and so on – are governed by the configuration of its atoms and the electrons that crowd around them. So if you could map the behaviour of all a material's electrons, you would know what it would be like, even if you had never seen it.

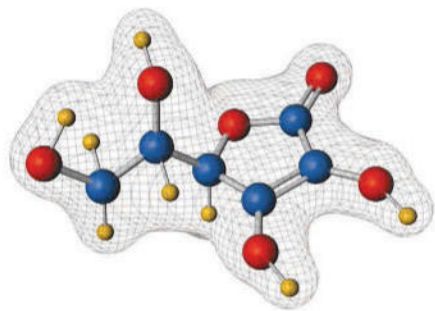
Herculean effort

In theory that's doable using Erwin Schrödinger's eponymous wave equation, which describes how any quantum system evolves in time. Yet solving this equation for anything but the simplest of atoms requires a herculean computational effort. Each electron influences the behaviour of all the others, meaning their properties must be computed simultaneously. For decades this complexity has meant that the only practical way of investigating the properties of materials has been to make them and measure their properties, one by one.

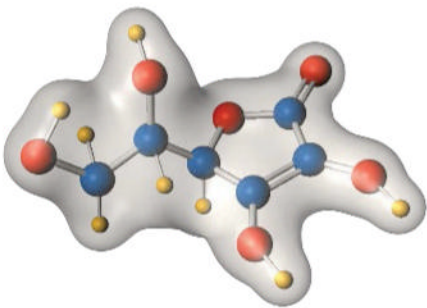
Half a century ago researchers began to look for workarounds. In 1965, theoretical physicist Walter Kohn, now at the University of California, Santa Barbara, developed the idea of treating bunches of electrons as one smeared-out entity. It was an idea that others, including chemistry theorist John Pople ➤

Electron smears

The properties of materials are governed by the arrangement of their atomic nuclei and electrons. Simulate that and we can screen virtual materials for any property we want without going to the trouble of making them. Those simulations hinge on a smart piece of maths called density functional theory.



Without this, calculating a material's properties involves calculating all the components in a complex network of interactions between the individual atomic electrons in a molecule (above), so you must solve the equation for all electrons simultaneously. Even in simple molecules the interactions are way too complex for existing computers to solve.



Density functional theory (DFT) gets around this by assuming that all the electrons being considered are in their lowest energy state and that their interactions aren't important. The properties of the material can then be recast as functions of the charge density surrounding the atoms (above). Today calculations on this more blobby basis are a fairly reliable guide to most materials' properties.



What holds back the electric car?

MAX WHITTAKER/REDUX/EVINE

with whom Kohn shared the 1998 Nobel prize in chemistry, would mould into a practical technique for calculating the properties of substances. They called it density functional theory, or DFT (see "Electron smears", left).

Although the technique made calculating the structure and properties of materials possible, progress was slow through the 1970s and 80s due to squabbles between different camps of physicists over the level of detail needed in the calculations. Various groups developed slightly different ways of carrying out DFT, some quicker and dirtier, others more finessed but requiring eye-watering computing power.

Arguments simmered for years over which versions of the calculations struck the right balance, but by the mid-2000s enormous advances in computing power rendered much of the disagreement obsolete and finding materials using simulations started to speed up. It was around this time that two chemists who had made a name for themselves refining DFT, Kristen Persson at the Lawrence Berkeley National Laboratory in California and Gerbrand Ceder of the Massachusetts Institute of Technology, began to attract attention – initially from one of the largest consumer goods companies in the world.

In 2005, executives from Procter & Gamble were on the hunt for an improved cathode for their Duracell brand batteries. Was it possible, they asked Persson and Ceder, to use supercomputers to screen all known compounds for the sort of thing they were looking for? It was. Equipped with \$1 million from P&G and free rein on the firm's supercomputers, the pair screened some 130,000 existing and imagined compounds and found 200 that fit the bill.

The scale of that exercise is what led Persson

and Ceder to propose the Materials Genome Project in 2010. The idea was that researchers shouldn't have to painstakingly make and test materials for any particular property. Instead, the details of every possible material's inner workings should be stored and pre-packaged in a database. State the property of interest, and it would spit out the virtual substance that fits the brief most closely. It was to be "the Google of material properties", Ceder says. In the early days there was even an interface for accessing it called "Mooglee".

Perfect properties

The idea quickly gained traction, and today Ceder and Persson's project – now rebranded as "The Materials Project" – is part of a much wider Materials Genome Initiative coordinated by the US federal government. Just about every US research outfit and government agency with an interest in science is involved, from Harvard University to the Department of Defense to NASA. Since 2011, \$250 million has flowed into the scheme, much of it spent on powerful computers that will "support U.S. institutions in the effort to discover, manufacture, and deploy advanced materials twice as fast, at a fraction of the cost".

To date Persson and Ceder's part of the project has calculated the basic set of properties for more than 58,000 compounds, says lead developer of The Materials Project Anubhav Jain, who is based at the Lawrence Berkeley National Laboratory – a lot of stuff, but only a start to the vision of sourcing new materials at a few key strokes.

But the team is already tackling some of the thorniest challenges. In March this year they published the world's largest set of data on the

elastic properties of inorganic compounds. These measure how atoms in a material move in relation to one another, and so can be used to make predictions of a whole host of more interesting properties.

Elasticity is tough to measure experimentally, because it varies so widely depending on the exact direction in which pressure is applied. Even earlier this year, entire research papers would be devoted to calculating the elasticity of a single combination of elements. It had taken decades to amass the elastic properties of just a few hundred compounds. The new database already has 1200. The project “has enabled us to automate the whole process”, says Wei Chen, the Berkeley Lab researcher behind the list.

One thing those elastic properties can help predict is a material's ability to conduct heat. Just last month, researchers at The Materials Project published details of a previously unknown class of thermoelectric materials that they had found after exploring the database. Thermoelectrics produce electricity as they warm up, a heat scavenging property that is potentially world-transforming: imagine a world where cars charge themselves by capturing exhaust heat, for instance. So far the best explored thermoelectric, bismuth telluride, is expensive and gives off toxic fumes if it gets too hot.

Having found a new group of thermoelectric compounds, the team went ahead and made one, a substance composed of thulium, silver and tellurium (*Journal of Materials Chemistry C*, doi.org/7f4). Sure enough, it had the modest thermoelectric properties the theory predicted. Of itself this material is barely more useful than bismuth telluride; for one thing thulium is vanishingly scarce. But that's not the point: it shows that the guiding principle of the project can work.

As soon as the new class of material had been discovered, the researchers started playing around with the atoms. Their latest iteration replaces rare thulium with the more common yttrium, and it more than doubles the thermoelectric effect. “We're systematically improving upon the base compound even though we haven't found the ‘it’ material yet,” says Jain.

It's not just thermoelectrics. The compounds that give fluorescent light bulbs their red, green and blue hues are in great

need of replacement: each of them contains so-called rare-earth elements such as terbium and europium that are in limited supply. It's a tough challenge because any new material must absorb and emit light at precise wavelengths to match our eyes' sensitivity.

In 2014, a collaboration involving researchers from the Lawrence Livermore National Laboratory and General Electric invented two replacements. One is based on zinc, phosphorus and oxygen, the other is aluminium nitride doped with manganese. DFT calculations helped work out the way the atoms must be organised to absorb light

“What if we can make all the materials we can imagine, and the ones we can't?”

in just the right way, says Steve Payne, who was part of the team. “With computers being so fast these days you can do a pretty darn good screen; you can learn things and spot trends,” he says.

Admittedly, human brain power is still needed to translate that learning into a new material. But the approach can also keep materials scientists from taking wrong turns. “The Materials Genome Initiative creates tools and methods that help in avoiding blind alleys,” says Alex King, director of the Critical Materials Institute based at the Ames Laboratory in Iowa, which was established through the MGI.

Take methane. We have long been on the

lookout for a way to compress and store it for use as a potential replacement for petrol, with a focus on a set of storage materials called metal-organic frameworks, or MOFs. About 10,000 MOFs have been made so far. To be vaguely competitive with petrol a would-be methane storage material needs to have an energy density of 12.5 megajoules per litre, according to the US Department of Energy. They were all way off the mark.

Under the aegis of the Materials Genome Initiative, researchers from several US universities and the Ford Motor Company have now computed the structures of some 650,000 existing and imagined MOFs, publishing the results in January this year (*Energy and Environmental Science*, vol 8, p 1190). From the structures alone the team worked out the size of the gaps between the materials' atoms and estimated how much methane could theoretically fit in. They quickly realised that not one bettered the methane sponges that had already been made, suggesting we should ditch MOFs altogether. DFT may have cut out several years of wild goose chase.

Closer to the “it” material is the latest news on the high temperature superconductors we need to make levitating trains mainstream. The recent discovery of a material that conducts electricity with no resistance at a balmy -70 °C – up from the previous record of -110 °C – has a lot to do with the genome-style approach.

The thing is, the material in question – hydrogen sulphide – only becomes a superconductor when subjected to 1.5 million atmospheres of pressure (*New Scientist*, 12 September, p 28). No one would have thought to subject it to those pressures were it not for a 2014 study from Chinese researchers used the same approach to compute the chemical's properties at a range of extreme pressures.

More unusual discoveries are hoped in the coming years as the Materials Project extends beyond a data repository and to a design centre. It has also recently launched an app that allows anyone to dream up a compound and submit it to Jain for computation. Another enables you to input the qualities you desire and then uses machine learning to suggest compounds that fit. These tools are designed so that anyone can begin with a handful of atoms and a rough idea of a material they want to make and begin generating ideas for compounds. Personal jetpack, anyone? ■

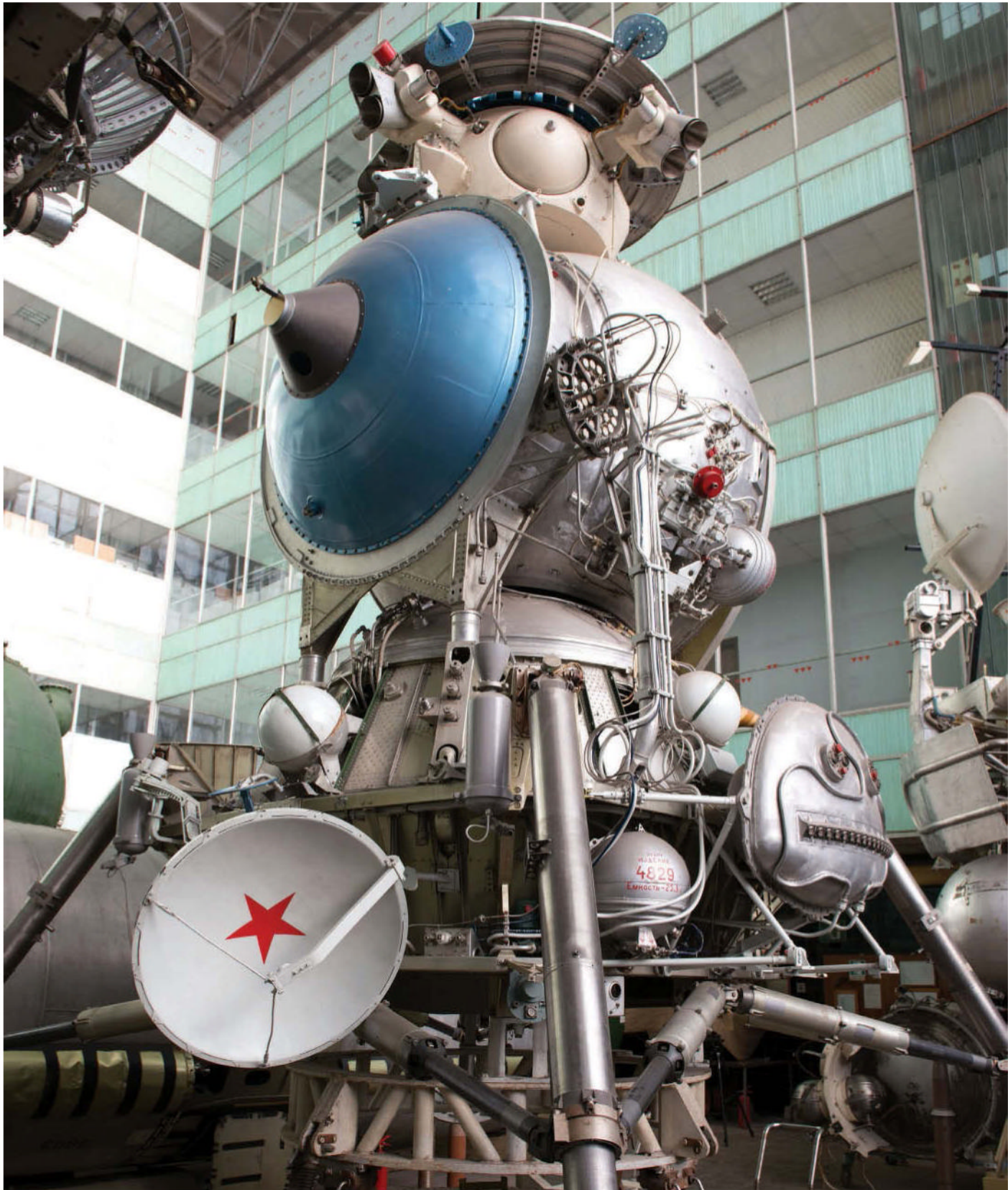
JOHN READER/SPL



Stone tools were an early breakthrough in materials discovery

Leigh Phillips is a journalist based in Victoria, Canada

STATE MUSEUM AND EXHIBITION CENTRE ROSIZO



London rolls out red carpet for space stars

Russia's most treasured 20th-century artefacts are now on loan – **Mick O'Hare** relives the glory of the Soviet space age

Cosmonauts: Birth of the Space Age, Science Museum, London
18 September 2015 – 13 March 2016

"IT'S THE RUSSIAN equivalent of the crown jewels." Doug Millard is not exaggerating when he describes the vast collection of Russian space hardware that makes up the exhibition *Cosmonauts: Birth of the Space Age*. It's the first time such a huge array of Soviet-era space hardware and memorabilia have been exhibited in one place at the same time and, perhaps more astonishingly, not in Moscow. "It's been four years of hard work to gather them together," says Millard, senior curator of the exhibition at London's Science Museum, "and, quite frankly, they're priceless."

This isn't hyperbole. The exhibits from the early era of space flight in the 1950s and 1960s, when the Soviet Union led the race into Earth orbit, are a source of huge national pride for both the Russian government and its people. Sputnik 1 was the world's first artificial satellite. Yuri Gagarin was the first man in space, Valentina Tereshkova the first woman. And Alexei Leonov was the first person to walk in space. The USSR was streets ahead of the US, its closest rival.

"For those Russians who remember the 1960s, in particular, there is an enormous sense of achievement and great

affection, particularly for Gagarin," says Millard. "More than once, when his name came up at meetings in Moscow, the tears would flow. It's on a par with the Soviet victory in the second world war. It transcends all the political changes, all of the memories of the Soviet Union, whether they are fond or not."

For fans of space history, it's an outstanding collection from 18 different institutions, museums and private collections throughout Russia. The hardware is a roll call of the golden age of space travel. There is Voskhod 1, the capsule for the first multiperson space flight in 1964. Soviet politicians were so keen for the flight to take place that spacesuits were left behind to reduce weight and so the three cosmonauts could fit inside a capsule designed for two.

And in the Space Race section of the exhibition sits Vostok 6, the craft that carried the first woman into orbit in 1963. The capsule has taken one hell of a battering, its heat shield ravaged. Fifty years on, it seems unthinkable a human could survive inside. But one did. Its commander Tereshkova was reunited with her craft on the opening day of the exhibition. "Every time I see it I touch it," she admits. "It is my best and most beautiful friend. It is my man."

"It's the spacecraft that took the first woman into space – something that will be remembered as long as we're on this planet," says Millard. "It was a tall order getting Vostok 6 to London. It wasn't on display in a public museum but belongs to Energia, the private Russian space enterprise." And sometimes the lack of sophistication is

brehtaking: the Voskhod and Vostok capsules appear, from the outside, to be little more than burnt metal balls with a hatch.

While both Russian and British governments were enthusiastic about the exhibition, Millard points out that the cultures of bureaucracy in both countries differed significantly. "There were lots of visits, negotiating, loads of letters. My goodness, so many letters. We all have different styles of operating, so we had to learn our opposite number's ways. But the momentum was always there. And this is the outcome."

Other exhibits are more esoteric. They include a space suit for a monkey and a pair of cardiovascular trousers. Yet, it's perhaps the human element that gives as much insight into the era as the impressive line-up of capsules, space suits and the

"The lack of sophistication is breathtaking – some capsules are no more than metal balls with a hatch"

1960s lunar lander that was kept secret from the West until 1989.

There's a letter from Maria Trofimova written in 1959 to Radio Moscow while she was employed at a worker's collective. She had contacted many institutions requesting to be sent into space in a satellite. "She wanted to serve her country, whatever the risk, whatever the danger. It could actually be my favourite exhibit. It's poignant stuff," Millard says. You'll also see the aluminium mug used by the head of the Russian space programme Sergei Korolev while imprisoned in the Gulag during government purges before and during the second world war. The exhibition is testimony to his extraordinary career.

"How do you put a value on all this?" Millard wonders. "There's a government indemnity insuring it all, but nothing here can be rebuilt or replaced. These items are beyond price." ■



Left: the Soviet lunar lander
Right: Valentina Tereshkova

Wild, silly and enlightening

What can the arts make of a world in crisis? **Simon Ings** interrogates some of Europe's festivals

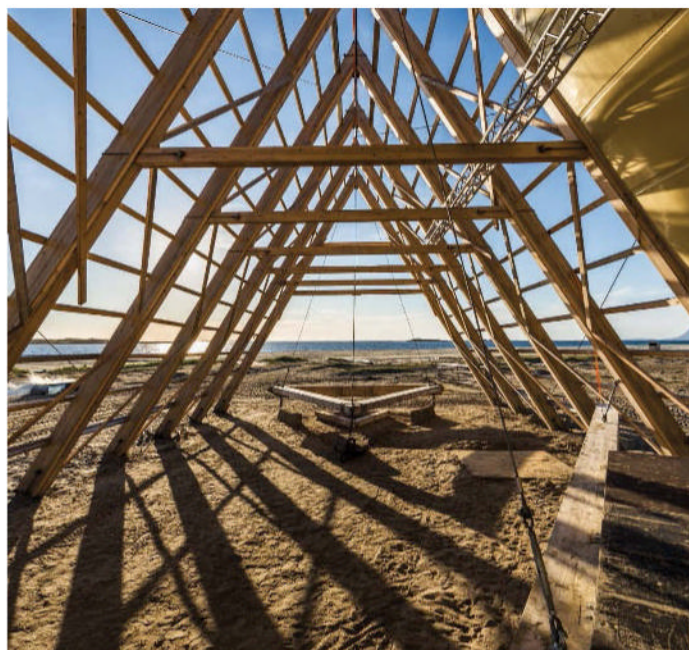
SITTING on a driftwood sculpture in the middle of a large paddling pool, a man in silver face paint and bodysuit – I think he is supposed to be a fish – is shouting his lungs up. He is attempting to express the emotions of the sea.

There's a lot of this sort of thing on the Scandinavian arts scene, and it's spreading. More often than not it doesn't work, but how other than by wild, ugly and very silly experiments will we work out how to express, in human terms rather than in figures, the enormity of climate change, mass extinction and the epochal depletion we are learning to call the Anthropocene?

"Disappearing Acts" was the theme of this year's Lofoten International Art Festival. A 24-year-old institution, it is held every other year on a cluster of islands off Norway's north-west coast, just above the Arctic circle. This year's festival explored several kinds of disappearance: people are leaving the countryside for the cities, while globally, the countryside itself is dying off in unexpected and unnerving ways.

There's paranoia in this vision, and a millennial impulse that has nothing to do with science. As the UN climate conference in Paris nears, however, and with Syrian refugees being spotted entering Norway from Arctic Russia by bike, some response beyond blind panic would surely be welcome.

At the Ars Electronica festival in Linz, Austria, a behemoth of the art, science and design scene now 36 years old, discrete "problems" find technical "solutions" in a distinctly dated manner. For



variety to its genome. Alas this is not true: turmeric is not infertile – it is another flowering ginger, which happens to have the option of reproducing via rhizomes besides producing seed.

This kind of intervention used to seem ingenious, then cute, but now it's irritating. Even when the premise is right, if our

"Artistic experiments help us express the enormity of climate change in human terms rather than figures"

deteriorating ecology has taught us anything, it's that our solutions to discrete problems only breed more problems down the road.

Why don't we just pay attention to what is happening to our world, and speak about that as honestly as we can? This is the idea behind SALT, a refreshingly low-key festival whose run on the Norwegian island of Sandhornøy has just ended. Over the coming years, it will circumnavigate Earth's most northerly settlements, from Greenland to the Faroes, from Scotland to Spitsbergen.

It has staged music concerts attended by thousands, but is most itself when a handful of visitors huddle in a shack made of driftwood and shipping containers to contemplate *Glimt*, an installation of moving lights by Norwegian artist HC Gilje that evokes the fleeting passage of living things across the landscape.

SALT's co-founder Helga-Marie Nordby apologised when I visited this September: it was so warm, you could bathe in the ocean and dry off in the sun. "It's not usually like this," she said. A long and eloquent silence followed. ■

example, it featured a "Future Mobility" expo, the star of which was the Mercedes-Benz F 015 Luxury in Motion self-driving car.

The F 015 is meant to exemplify a future "when there are more robots than people working in factories, everything is intelligently interlinked, autos drive autonomously and drones

deliver the mail". Don't let the automobile styling fool you, this "car" is the size of a truck, and stuffed with exotic materials. Nearby, the curators have undercut it quite brilliantly by placing a "Fahrradi Farfalla FFX", Austrian artist Hannes Langeder's absurdly overstyled "sports car", made from bicycle parts and gaffer tape, and sprayed with bright red lacquer.

Ars Electronica is full of such arch gestures. This year it also featured PSX Consultancy, an international collaboration to produce "sex toys for plants". Information boards explain each plant's reproductive "problem" and then propose a "solution". For turmeric, an infertile plant that reproduces only via its rhizomes, weather balloons will carry the plants to the stratosphere, where, it is hoped, the increased solar radiation will introduce some



Emotional "fishman" (right); replica fish drying racks (top) at SALT

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Harvard University Faculty of Arts and Sciences, Cambridge, MA Department of Chemistry & Chemical Biology TENURE-TRACK PROFESSOR



Position Description: The Department of Chemistry & Chemical Biology seeks to appoint a tenure-track assistant professor in the open field of chemistry and chemical biology. The appointment is expected to begin on July 1, 2016. The tenure-track professor will be responsible for teaching at the undergraduate and graduate levels.

Basic Qualifications: Doctorate or terminal degree in chemistry or related discipline required by the time the appointment begins.

Additional Qualifications: Demonstrated excellence in teaching is desired.

Special Instructions: Please submit the following materials through the ARIeS portal (<http://academicpositions.harvard.edu/postings/6320>). Applications must be submitted no later than October 15, 2015.

1. Cover letter
2. Curriculum Vitae
3. Teaching statement (describing teaching approach and philosophy)
4. Outline of future research plans
5. Names and contact information of 3-5 references (three letters of recommendation are required, and the application is complete only when all three letters have been submitted)
6. List of publications

Harvard is an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Contact Information: Helen Schwickrath, Search Administrator, Department of Chemistry & Chemical Biology, Faculty of Arts and Sciences, Harvard University, 12 Oxford St., Cambridge, MA 02138. Phone: (617) 495-8190.

Contact Email: Helen@chemistry.harvard.edu

Washington University in St. Louis

Faculty Positions in Biochemistry and Molecular Biophysics

The Department of Biochemistry and Molecular Biophysics at Washington University School of Medicine invites applications for several tenured/tenure-track faculty positions at the level of Assistant/Associate/Full Professor. Successful candidates will have established a strong record of research. Applicants seeking tenured positions must have a strong record of external funding.

Outstanding individuals working in any area of biochemistry and molecular biophysics are encouraged to apply. The candidate's research should be aimed at addressing fundamental questions related to molecular mechanisms of biological or biomedical relevance. Current research in the department spans a wide range of topics including computational biology, membrane proteins, molecular motors, nucleic acid / protein interactions, protein structure, enzymology and signal transduction. Additional information about the department is available at <http://www.biochem.wustl.edu>. Washington University has a highly interactive research environment with vigorous interdisciplinary graduate and medical scientist training programs.

Applicants should email their curriculum vitae, brief description of their research interests, and contact information of three individuals to the Search Committee at bmbsearch@biochem.wustl.edu. The committee will request letters from these individuals as necessary.

Completed applications will be reviewed on a rolling basis, starting immediately. For full consideration, applications should be received by December 1, 2015.

EOE/Minorities/Vets/Disabilities. The School of Medicine at Washington University is committed to finding solutions to global health problems, including ones that affect minority and disadvantaged populations.

Annual Biomedical Research Conference for Minority Students (ABRCMS)

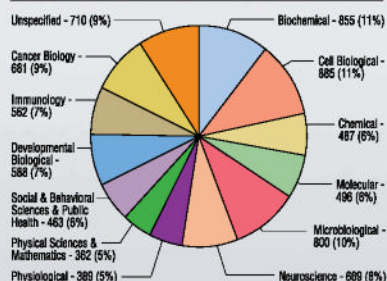
Washington State Convention Center • Seattle, WA • November 11-14, 2015



ABRCMS advances undergraduates and postbaccalaureates from underrepresented populations, including those with disabilities, in science, technology, engineering and mathematics (STEM) along the path toward graduate-level training. The conference features 1,700 poster and oral presentations, scientific sessions, professional development and networking sessions, and approximately 325 exhibit booths showcasing summer research and graduate school opportunities.

"Attending and winning in my category was one of the best experiences in my scientific life. Coming from my background, I doubted myself in the past. I now feel confident because when I presented my poster I left like I belonged. This conference really made me believe that I can pursue a career in science." STUDENT

2014 Distribution of Scientific Disciplines



Important Deadlines

Abstract Submission: September 11, 2015

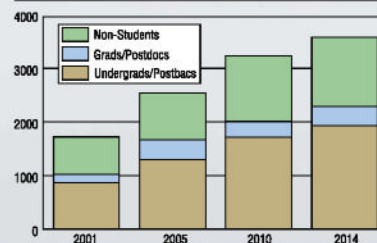
Travel Award Application: September 11, 2015

Judges' Travel Subsidy Application: September 25, 2015

Discount Registration: October 19, 2015

For more information, please visit: www.abrcms.org.

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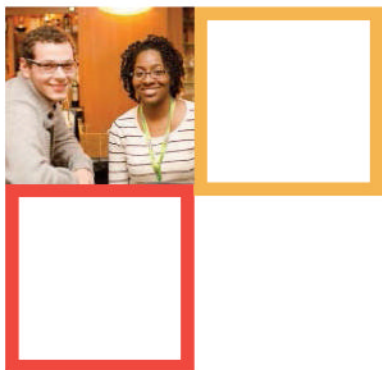


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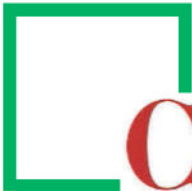


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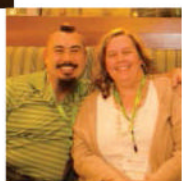
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KANSAS STATE UNIVERSITY



Assistant/Associate Professor Physics Education Research Kansas State University

The Department of Physics at Kansas State University seeks a faculty member to join its physics education research (PER) group. Experience with research on the teaching and learning of physics that complement and/or expands the existing PER efforts at KSU will be considered favorably. The successful candidate will be appointed at a rank of tenure-track Assistant or Associate Professor in the Physics Department. Candidates must present credentials which will justify appointment at one of these levels. Minimum requirements include a Ph.D. in physics education research or equivalent and research experience beyond the doctorate.

The Department has an outstanding physics education research program (KSUPER), which was founded in 1972. At present KSUPER includes two faculty members. A detailed description of research activities, post-docs and graduate students in KSUPER can be found at <http://www.phys.ksu.edu/ksuper>. For further information contact Eleanor Sayre (esayre@phys.ksu.edu) or Dean Zollman (dzollman@phys.ksu.edu).

The successful candidate will also demonstrate a strong commitment to teaching and mentoring of students and to serving a diverse population. He/she will be expected to obtain external funding for research activities, collaborate with other faculty in physics and other academic departments and build a national and international reputation in PER.

Applications should be sent, to PER Search Committee, 116 Cardwell Hall, Kansas State University, Manhattan, KS 66506-2601 or to persearch@phys.ksu.edu. Applications should include a cover letter that addresses qualifications for the position, a curriculum vita, and statements of research and teaching interests. The applicant should arrange to have three letters of reference sent to the address above.

Screening of applicants will begin on December 1, 2015, and continue until the position is filled.

Kansas State University is an Equal Opportunity Employer of individuals with disabilities and protected veterans and actively seeks diversity among its employees. Background checks required.

KANSAS STATE UNIVERSITY



ASSISTANT/ASSOCIATE PROFESSOR SOFT MATTER EXPERIMENT CONDENSED MATTER GROUP DEPARTMENT OF PHYSICS

The Department of Physics at Kansas State University seeks an experimental physicist with research interests in soft condensed matter physics. Areas of interest include nanoparticle assembly, biological problems at the cellular and molecular levels, emergent phenomena, macromolecules, structured fluids, colloids and aerosols, and light scattering and its application to these systems. Such a scientist might engage in experimental research at the molecular or continuum levels of these physical or biological systems. Cross disciplinary research plans that overlap with ongoing AMO projects in the department (strong field laser-matter interactions, plasmonics, ultrafast charge transport) will be reviewed with interest, but are not required. The successful candidate will be appointed at the rank of tenure-track Assistant or Associate Professor in the Physics Department. Candidates must have a PhD in physics or a closely related field. To be considered for the Associate level position candidates must present credentials which will justify appointment at that level. The successful candidate should also demonstrate a strong commitment to teaching and mentoring of students and to serving a diverse population.

The Department has outstanding experimental and theoretical Condensed Matter physics programs involving seven faculty members most of whom are involved in research related to soft matter physics. Faculty research interests include synthesis and self-assembly of nanoparticles, surface structure and surface interactions of nano/bio components, light scattering, metallic and conducting polymer nanowire fabrication and applications, cellular adhesion and migration, aggregation phenomena for both proteins and particles, and nanostructured magnetic systems. The soft matter group has strong ties and collaborations with faculty in Chemistry, Biology, Biochemistry, Mechanical Engineering, Chemical Engineering, Grain Science, and the Terry C. Johnson Center for Basic Cancer Research. A description of research in the physics department can be found at:

<http://www.phys.ksu.edu/research/condensed-matter.html>

Applications should be sent to The Condensed Matter Search Committee, 116 Cardwell Hall, Kansas State University, Manhattan, KS 66506-2601 or to softmattersearch@phys.ksu.edu. In addition to a curriculum vita, applications should include statements of research and teaching interests. Candidates should arrange for three (3) letters of reference to be sent as well.

Kansas State University is an equal opportunity employer and actively seeks diversity among its employees. Background check required.



RADCLIFFE INSTITUTE FOR ADVANCED STUDY HARVARD UNIVERSITY

Academic Fellowships

The Radcliffe Institute Fellowship Program at Harvard University welcomes fellowship applications in natural sciences and mathematics. The Radcliffe Institute for Advanced Study provides scientists the time and space to pursue their career's best work. At Radcliffe you will have the opportunity to challenge yourself. Meet and explore the work of colleagues in other fields. Take advantage of Harvard's many resources, including the extensive library system. Radcliffe Institute Fellowship Program invites applications from people of all genders, and from all countries. We seek to build a diverse fellowship program.

Scientists in any field who have a doctorate in the area of the proposed project (by December 2014) and at least two published articles or monographs are eligible to apply for a Radcliffe Institute fellowship. The stipend amount of \$75,000 is meant to complement sabbatical leave salaries of faculty members. Residence in the Boston area and participation in the Institute community are required during the fellowship year.

Applications for 2016-2017 are due by October 15, 2015.

For more information, please visit www.radcliffe.harvard.edu or email sciencefellowships@radcliffe.harvard.edu.

Berkeley

Department of Chemistry
UNIVERSITY OF CALIFORNIA Faculty Position in Chemistry

The Department of Chemistry at the University of California, Berkeley invites applications for one tenured faculty position at the associate/full professor level with an expected start date of July 1, 2016 in the broadly defined field of experimental physical chemistry. The basic qualification for this position is a Ph.D. or equivalent degree in Chemistry or a related field at the time of application.

All applicants should submit their most recently updated curriculum vitae, a three to five-page statement of future research plans and a statement of teaching. Additionally, please provide contact information for three to five references. We will only contact your referees if you are a finalist for the position, and we will seek your permission before doing so. A cover letter is optional. Applications should be submitted electronically through our web-based system at: <https://aprecruit.berkeley.edu/apply/JPF00804>.

All recommendation letters will be treated as confidential per University of California policy and California state law. Please refer potential referees, including when letters are provided via a third party (i.e., dossier service or career center), to the UC statement on confidentiality (<http://apo.berkeley.edu/evalltr.html>) prior to submitting their letters.

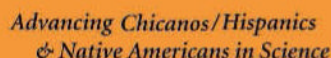
The deadline to apply for this position is November 2, 2015. Please direct questions to Lauren Nakashima (lnakashima@berkeley.edu).

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, age or protected veteran status. For the complete University of California nondiscrimination and affirmative action policy see: <http://policy.ucop.edu/doc/4000376/NondiscrimAffirmAct>.

UC Berkeley is committed to diversity in all aspects of our mission and to addressing the family needs of faculty, including dual career couples and single parents. The Department of Chemistry is interested in candidates who will contribute to diversity and equal opportunity in higher education through their teaching, research, and service.



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Speak Now or Forever Lose Your Science

The rarefied world of academic science may be what drew many researchers to the scientific endeavor, but remaining isolated from the populace could harm their chosen profession and undermine progress in science and technology.

By all estimates, the public's understanding of science – from basic principles like the scientific process to complicated concepts like string theory – is poor at best. An extreme example of this pervasive problem is Sarah Palin's mockery of fruit fly research during the 2008 campaign trail. In a speech on autism, Palin stated that she and then running mate John McCain would nix projects that "really don't make a whole lot of sense" and have "little or nothing to do with the public good... things like fruit fly research in Paris, France." Little did she know that studies on *Drosophila* fruit flies have yielded a number of insights into autism and other illnesses, and in fact underpin the whole of modern genetics.

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Palin might have an ineffectual grasp of science and technology, or she may be pandering to constituents who feel little connection to science. The average Joe doesn't necessarily appreciate the value of model organisms or the years of research and development that go into making a single drug, two aspects of the scientific endeavor that most researchers take as universal truths. And why should they? Too often scientists are reticent to leave their sphere of learning and investigation to engage the general public, choosing only to speak out when awakened to the goings-on of the outside world by statements like Palin's or the threat of cuts in federal funding.



No time to be silent

The issues faced by today's researcher amount to more than just mere insults and threats. According to an analysis by the American Association for the Advancement of Science (AAAS), federal spending on research and development plummeted by 16.3 percent from 2010 to 2013. Support for R&D hasn't dropped that fast since the end of the space race in the 1970s. With continued blows like sequestration and government shutdowns, many scientists are spending more time writing and rewriting grants than they are doing the research itself. A popular bumper sticker circulating in San Diego area reads "A 10% payline isn't funding. It is a lottery."

The outlook is bleakest for the youngest scientists, many of whom are reconsidering their choice of profession or looking at opportunities outside the United States. In 1980, close to 18 percent of the scientists holding a coveted NIH-funded RO1 grant were age 36 and under. As the pie of NIH funding has continued to shrink, that number has fallen to about 3 percent. While the U.S. investment in science has flat-lined, other countries have upped their commitment.

For example, the Beijing Genomics Institute, only one of many such facilities in China, has more capacity to sequence human genomes than all of the genome centers in the United States combined. As the director of the National Institutes of Health (NIH) Francis Collins noted, funding cuts have left scientists demoralized.

"We're losing what we've already invested in and funding fewer grants," said Collins, speaking at Research!America's 2013 National Health Research Forum. "Which of those would have been the next breakthrough in cancer? Which of those would win the Nobel Prize in another twenty years? We'll never know. To sit here and say this is just how politics works is not okay. We are undertaking a noble enterprise that can make a difference in the health of ourselves and our families. We should be making a lot of noise."

To read the complete article, visit the Burroughs Wellcome Fund site at: New Scientist

<http://www.bwfund.org/newsroom/newsletter-articles/speak-now-or-forever-lose-your-science>

EDITOR'S PICK



Does parenthood make us happier?

From Brian Horton

Georgia Grimmond asks whether parenthood makes us happier (5 September, p 40). But the studies she quotes are looking at the wrong group of people. Most found that the biggest increase in happiness was in parents over 40. Yet they didn't take the next logical step to show that it isn't children that make people happy, but grandchildren.

A grandparent can have all the fun of playing with children, but when they misbehave you just hand them back to their parents. Clearly we have children only so we can pressure them to have their own children, in order that we become grandparents and finally achieve happiness. *West Launceston, Tasmania, Australia*

From Richard Epworth

You report that the happiness of older parents persists with increased numbers of children, unlike that of younger parents. If the surveys were conducted within the last decade, and asked parents only about their current situation, some of this may be the consequence of different generations having differing expectations of personal happiness.

The assumption that you deserve to have a job, children and material trappings is a comparatively recent one; older parents may have had lower expectations. For that matter, they may also have been better off. *Sawbridgeworth, Hertfordshire, UK*

Dry lands are not deserted lands

From Jonathan Davies, International Union for Conservation of Nature, and Irene Hoffmann, Food and Agriculture Organization of the United Nations

In your interview with Mike Mason about his plan to grow cacti on drylands for biofuel he repeats a common misconception: that semi-arid land has little use (15 August, p 25). This ignores the existence of over 500 million economically active land users in the world's drylands.

The UN Food and Agriculture Organization estimates that drylands produce about a third of the world's livestock products. And according to data held by the International Union for Conservation of Nature they are home to a third of its biodiversity. Land users in the drylands may need some more convincing about the merits of switching to cactus farming.

The fact that so much of the dry land is not covered by any legal title of ownership does not mean that it is freely available. We invite Mason to visit some of these people to learn more about the many different uses they already have for their land. *Gland, Switzerland*

Before the beginning...

From Chris Ford

It always surprises me that there are scientists who can't accept that time and space began with the big bang (5 September, p 30). They succeed only in pushing the problem further back. You must accept either a beginning at some point or an infinite past, with all the horrors that infinity implies – everything possible has happened an infinite number of times. Infinity always spells the death of

reasonable physics. I suppose we could all be whizzing infinitely round a closed loop, but that sounds just as bad.

Personally, I'll stick with the good old big bang – everything has to start somewhere. *Walsall, West Midlands, UK*

Mind isn't all about you, you know

From Ian MacDonald

It's all very well for Peter Halligan and David Oakley to say that your unconscious mind tricks you into believing you have a sense of self (15 August, p 26), but what exactly is experiencing this self illusion? *Bath, Somerset, UK*

From Gwydion Williams

Your article on consciousness evolving for the greater good, not just the self, suggested to me that this needs a catchy name, like other consciousness models. How about the "newsroom model": a coherent report of things that were decided elsewhere. *Coventry, West Midlands, UK*

From Angus Martin

How disappointing to find that Halligan and Oakley ignore fundamental evolutionary principles in their theory of consciousness. We know of no way in which the sense of self could have "developed for the benefit of the social group, not the individual".

For a sense of self (or any other trait) to be present it must be of benefit to the individual manifesting it; of course it may also have spin-off benefits for other individuals.

The supposition that an adaptive strategy "could be beneficial to species survival" overlooks the reality that natural selection is not and cannot be a force promoting species survival.

But the authors' conclusion, that consciousness "provides a powerful evolutionary advantage"

by "extending each individual's understanding of the world", in fact fills the bill so completely that it obviates any need for the group-based and species-based postulates that precede it. *Camberwell, Victoria, Australia*

How do bicycles stay upright?

From Alan Robinson

Without riders, bicycles fall over, so it's no surprise physicists still can't explain why they stay upright (5 September, p 30).

Handlebars control the course of the contact between wheels and road, but give no direct control over the path of the rider above. They are used to maintain an unstable "upright" equilibrium – except uprightness is only for going in straight lines. Bends require inward lean to produce the centripetal force that takes the rider round the same bend as the bike. It's remarkable how cyclists "get the knack of it" without knowing the mechanics.

Bike riding isn't a job for the cerebrum. Maybe that's why physicists can't get to grips with it. *York, UK*

From David Boswell

This is the wrong question. It should read "How does a human stay upright on a bicycle?" The ability to cycle must lie in proprioceptive mechanisms, presumably centred on the inner ear, and our visual system, along with fine-tuned neuromuscular control. *Timsbury, Somerset, UK*

How to breed spermless boar

From Keith Walters

You write that the company Recombinetics has "disabled a gene essential for testicular development [in pigs]... the idea

f “After the bees return, anti-environmentalists will say ‘You said bees were disappearing and now look!’”

Steve Ridge predicts the price of a successful response to a crisis – in this case the crisis of bee die-offs (19 September, p 7)

is that the company will sell semen with this disabled gene for farmers for use in artificial insemination” (15 August, p 10). So, er... how do you get semen from boars with no testicles? *Riverstone, New South Wales, Australia*

The editor writes:

■ The answer involves a second set of boars, gene-edited to prevent them from producing sperm. These would act as incubators of sperm from the set of boars with undescended testicles.

Handed festivals north and south

From Ken Pettett

When discussing why Iron Age banquets might favour the right forelegs of pigs, you report Brian Hayden saying that “in many societies going sunwise is standard protocol in rituals. If you face the sun that means going from left to right” (15 August, p 12). This is true in the northern hemisphere.

The fact that the sun goes from

right to left in the south presents an ideal way to test his theory: banquet rituals there would favour the left leg.

Were right legs favoured simply because people are generally suspicious of anything to do with left-handedness? Or is cutting off the right leg more natural for right-handed people: a butcher could tell us about that.

Sandy, Bedfordshire, UK

When is it time to be a gym bannee?

From Naomi Stanford

The idea that music has the capacity to raise people’s pain thresholds may explain why many fitness centres set exercise classes to music (8 August, p 10). In my experience, music in gyms is played extremely loudly, with the instructor shouting above it. Class members are there only for an hour at a time; but I wonder what damage is being done to the instructors’ hearing. Should they be protected?

London, UK

Archery and out-of-body experience

From David Hulme

Anil Ananthaswamy’s review of the book *Kabbalah: A neurocognitive approach to mystical experiences* (8 August, p 42) led me to wonder whether the world of sport might be ripe for investigations into the out-of-body phenomenon.

I can imagine that long-distance runners might experience the feeling of separation from their physical selves as they pound rhythmically mile after mile. From a personal viewpoint, I once had a fleeting moment of separation from my physical self while practising archery.

It came during a period of intense training when a combination of concentration and repetition made me feel as if I was observing myself going through the shooting process and it lasted while I loosed six arrows.

The central premise of *Zen and the Art of Archery*, first published by philosopher Eugen Herrigel in 1948, is that through years of

practice a physical action becomes so effortless that you can perform complex movements without conscious thought. It might not be out-of-body, but it is part of the same continuum.

Stockport, UK

Anonymity isn’t as easy as that

From Michael Zehse

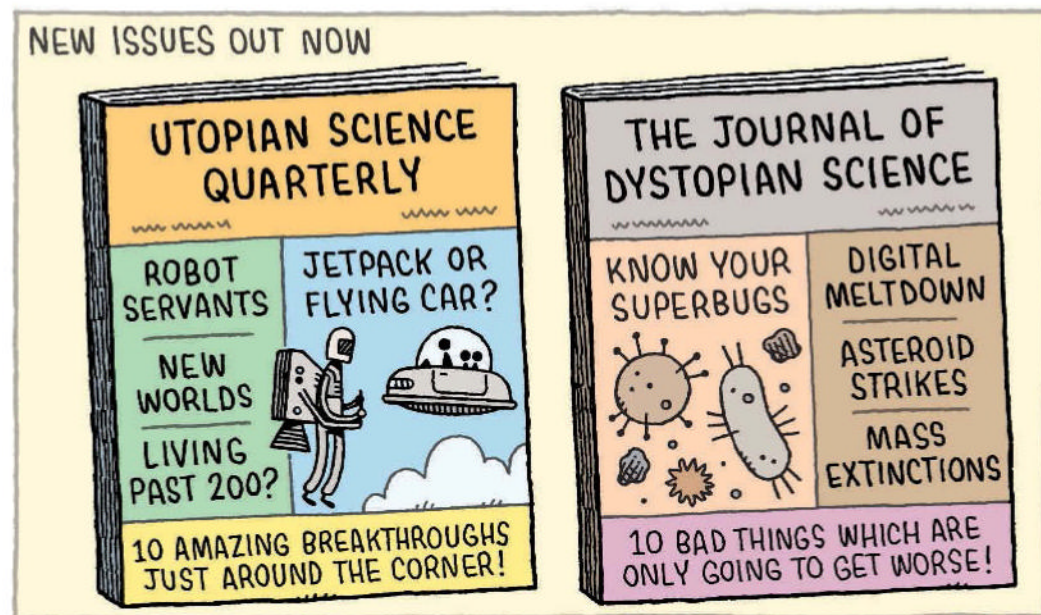
You report Krzysztof Szczypiorski saying that as online data breaches continue people will start to use smarter ways to disguise illicit behaviour.

He observes that if people had adopted precautions such as email accounts under a different name, and prepaid credit cards that can be loaded anonymously, for example, that “would have saved a lot of people’s marriages” (29 August, p 10).

Thanks to stringent money-laundering regulations, as far as I know it is not now possible to legally obtain and use “prepaid credit cards that can be loaded anonymously” in the UK.

London, UK

TOM GAULD



For the record

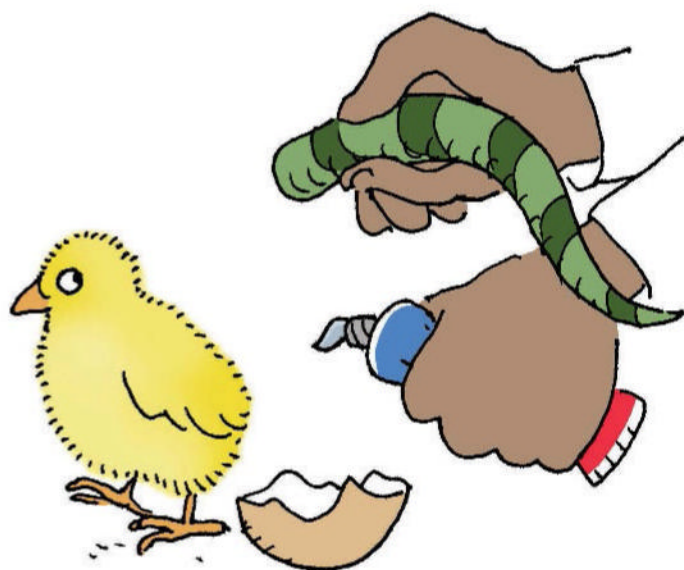
■ We missed. Peter Godfrey-Smith, who presented evidence of octopuses throwing things, is in fact professor of philosophy at the Graduate Center, City University of New York (29 August, p 14).

■ When we referred to Earth’s first atmosphere we should simply have said that it would not support life (25 July, p 26).

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THE Ig Nobel Prizes have for 25 years honoured achievements that make you laugh, then think; and this year's batch was no exception.

Bruno Grossi and four colleagues earned a feather in their cap by gluing artificial tails onto the backsides of chickens. They won the Ig Nobel in biology for addressing a timeless palaeontological problem: how did two-legged predatory dinosaurs walk about the Cretaceous world?

Birds are their closest living relatives, but they balance by crouching, and walk by moving their knees and lower legs with their thighs horizontal. The strut of a crow or rooster can't match that of a dinosaur because the birds are missing something vital - the fleshy mass of tail that served as a counterweight to the dinosaur's head and neck.

To see how chickens would walk with heavy tails, Grossi glued fake tails onto the rear ends of 2-day-old chicks, replacing them with larger tails until the birds were 12 weeks old. And hey presto, chicks with the

heavy tails started walking with their legs more upright and more motion in their hips.

A PAPER on the limits of paternity bore fruit for Elisabeth Oberzaucher and Karl Grammer of the University of Vienna, Austria, who took the prize in mathematics.

They considered Moulay Ismail ibn Sharif, a Moroccan emperor who ruled from 1672 to 1727 and holds the official Guinness World Record for fecundity, with 888 children.

Earlier studies had suggested his record was exaggerated, so Oberzaucher and Grammer developed a model to test how many copulations per day were necessary to reach that staggering output.

The answer was a modest once or twice a day, depending on how fertile the women were, making the emperor's record plausible. Moulay Ismail had 500 concubines as well as four wives

to help him deliver his record, but Oberzaucher and Grammer say a smaller harem would have sufficed: they calculate peak paternity would require a harem of only 65 to 100 women.

MARK DINGEMANSE, Francisco Torreira and Nick Enfield of the Max Planck Institute for Psycholinguistics in Nijmegen shared the literature prize for explaining why people around the world say "Huh?" when they don't understand what they hear.

The sound and meaning of "huh" in languages around the world varies much less than expected - only about as much as "dog" varies among different dialects of English. Yet it's not an instinctive sound like a grunt; people must learn it, like other words. So why do all "huhs" sound alike?

They suggest that the sound is very effective at informing other people that you can't understand them. Or, as the three wrote, "it is the result of convergent cultural evolution: a monosyllable with questioning prosody and all articulators in a near-neutral position." To which Feedback says, "Huh?"

DAVID HU and his colleagues are flushed with success after collecting the physics prize for their study into urination.

Their winning study was precipitated when Hu was potty-training his son, and noticed the little boy took as long to pee as he did. Further research led Hu and his colleagues to discover all mammals over 3 kilograms empty their bladders in roughly 21 seconds, even though their bladder capacities range from 5 millilitres in a cat to 18 litres in an elephant.

The bigger the bladder, they found, the more hydrostatic pressure there is pushing urine flow through the urethra, and thus the faster the flow. So it all averages out, even for humans. The lack of difference among animals may mean it's not very important for survival, the authors suggest.

ON THE subject of politicised scientific names (12 September), Guy Cox reports that the giant redwood was originally christened *Wellingtonia gigantea* by a patriotic John Lindley.

However, Wellington's towering victory was short-lived: Lindley failed to realise that the war hero's name had already been taken by a group of shrubs in the Sabiaceae family.

"Cutting a very long botanical story short," Guy explains "eventually the giant redwood was put into a related genus *Sequoia*, named in honour of the Cherokee man who developed a written language for his tribe - and in my opinion he absolutely deserves it."

PAPER titles that possess brevity and wit gain more citations (12 September). John Woodgate reports a *Bell System Technical Journal* paper titled "The square root of a tree". This is not exactly



humorous, John admits, "but very intriguing, unless you are the sort of mathematician to grasp the meaning at once."

MEANWHILE, those who remember Lonnie Donegan's earworm will be pleased to know that a friend of Chris Evans co-authored a paper on risks of transferring infections through ear inspections, the title of which was "Does your earwax lose its pathogens on your otoscope overnight?"

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Climate change could submerge its launchpads, NASA has warned. Patrick Fenlon wonders why they don't contact the US navy, who "have lots of experience in launching rockets from underwater"

Off colour

I spotted this blackbird in the garden (see photo). It is not black but light grey, and it did not have pink eyes so I guess it is not an albino. It spread its wings and lay in the sun; in due course it flew off. I've never seen a blackbird with this colouring before. Can anyone tell me more about it?

(Continued)

■ Further to previous answers, I think this bird is sunbathing, not "anting". The ultraviolet-B rays in sunlight facilitate a crucial step in the biosynthesis of vitamin D. In humans this occurs directly in the skin, but in birds the skin is shaded by feathers.

To resolve this, birds use an oil secreted by the uropygial gland,



or preen gland, near the base of the tail. This contains a precursor steroid that is converted into vitamin D by sunlight. The bird spreads this oil on its feathers by preening, then suns itself either as shown in the photograph, or more briefly in flight, and consumes the photosynthetic product with the next preening.

Perhaps this prolonged sunning behaviour is seen mostly in the spring because of a vitamin D deficiency acquired during the dark winter.

*Charles Sawyer
Byron Bay, New South Wales,
Australia*

A mast-see

Tall masts and towers have warning lights to make them visible to aircraft pilots. But how does the autopilot system know of the presence of such tall, relatively thin structures? I assume that the autopilot cannot see the lights.

■ The simple answer is that the autopilot cannot see the tall masts. So why do planes rarely hit them? The answer lies in the fact that there are two types of flying protocol: visual flying rules (VFR) and instrument flying rules (IFR). In VFR flying it is the pilot's responsibility to see and avoid obstacles, so it is only allowed when visibility is good.

Commercial airlines must fly under all conditions, so they always fly under IFR. All aircraft using those rules reserve a flying pathway through the sky: these permitted routes are known to be completely free of all barriers such as tall masts and mountains.

The autopilot serves only to keep the aircraft safely flying along its pathway. Controllers on the ground, by means of radio communications to the pilot, manage the separation of IFR

aircraft by allowing only one plane at a time into an individual path segment. The system works remarkably well.

It is a legal requirement to keep new towers from intruding into IFR routes. If a tower must go into one, then it can only be constructed after the pathway has been adjusted to avoid the proposed tower. So tower avoidance in IFR flying is a matter of planning the flight to stay in the permitted airspace.

"Should the pilot ask the autopilot to fly out of safe airspace, nothing prevents it from hitting a mountain"

Should the pilot ask the autopilot to fly outside that safe airspace, there is nothing at all to prevent the plane from hitting a tower or even a mountain. A further problem is when a rogue plane ignores the rules and intrudes into the reserved airspace.

Hopefully in such situations the controller on the ground will see this on their radar and tell the IFR pilot to immediately change course and avoid a possible collision.
*Ed Gauss (former bush pilot)
Niwot, Colorado, US*

This week's questions

DEEP FRAISE

How long may fruit be kept in a domestic freezer while still

retaining reasonable levels of nutritional value?

*A. Gardener
Haywards Heath, West Sussex, UK*

ROSE NOSE

My golden retriever is "Dudley-nosed", meaning it has a pink nose rather than a black one. Such noses were first noticed in bulldogs from Dudley in Worcestershire, UK, hence the name. If this is a genetic mutation, how could it jump to other pure-bred dogs?

*Alan Moskwa
Joslin, South Australia*

JUDGEMENT BALL

When a line call is contested at the Wimbledon tennis championships, an animated review is displayed showing the trajectory of the ball and its impression on contact with the court. Similar images are used in cricket. How are these images generated and how do we know they are accurate?

*Robert W. Cooke
Holt, Norfolk, UK*

GALAXY TWIRL

Are the spiral arms of galaxies evidence for gravitational waves? If not, what creates these arms?

*Steve Miall
Higher Poynton, Cheshire, UK*

LUMBER'S UP

Can one determine which end of a plank taken from a tree trunk was pointing upwards as it grew?

*Ross Kinneir
Bristol, UK*

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